PURPOSE OF PUBLICATION

This publication incorporates the results of research and development carried on in the laboratories and subsidiaries of FUJIFILM Corporation. It includes papers and reviews related to imaging technologies such as silver halide photographic materials, printing materials and electronic cameras, data recording technologies such as magnetic recording media and optical discs, organic material design technologies such as materials for display and electronic device, optical design technologies, medical and life science technologies, information system and software development technologies, and so on. Original papers submitted to this journal are published in the Japanese language with an opening English language abstract, and papers which have already been printed in other scientific journals are reproduced from said journals in unmodified form. After the main texts listed are printed papers which have been found in the JDreamII-JSTPlus file and our company’s own file until November, 2010.

Editorial policy intends that content be accurately provided to the reader. Indulgence is begged for character usage and entry methodologies in materials not directly related to the subject at hand which may result in some lack of unity in expression.
After the global recession triggered by the Lehman Brothers collapse, which had a huge impact on Japanese industries, the world economy finally got back onto a recovery path, boosted by increasing demand from emerging nations in late 2009 and in 2010. The Fujifilm Group, having successfully reestablished a robust corporate base following its structural reform, has taken a similar upward turn and anticipates excellent results for the period ending March 2011. This marks the first step in a V-shaped recovery, which is sure to make the “Second Foundation” of our Group a reality.

Having said that, the world is still experiencing some economic instability, as evidenced by the Eurozone financial crisis. Amid such volatility, the Japanese economy is still neglecting certain necessary tasks, falling behind in entering the fast growing markets of emerging nations, and being slow to establish new economic zones such as the Trans-Pacific Partnership (TPP). Although the future is uncertain, inaction is unacceptable.

At a time like this, the focus of discussion for the growth and development of a company has been shifting from existing operations — simply considering “how to enhance the company's market competitiveness” — to a comprehensive strategy that considers “how to enhance the worth of the corporation using the entire company’s synergy.” We recognize that in the case of technology companies like us, instead of adopting narrow targets, such as “creating better yet more affordable products than those of our competitors for the existing market,” the broader goal of “creating greater value for society by continuing to innovate through R&D” is the challenge we must address for the survival of the company. Put another way, there has never been a more important time than now for the purpose of our R&D to be questioned in our corporate management.

For technology companies, the underlying strength from which the worth of the corporation can be enhanced is its R&D activities. This may not be revelatory, but in reality, it is no easy task to increase the true value of the corporation through R&D. In order for the role assigned to our R&D activities to be fulfilled with certainty through our daily corporate activities, it is necessary to build and implement a business model based on a thorough evaluation of how much value the products and services derived from our R&D activities offer society, by considering this issue from multiple viewpoints and both short- and long-term perspectives.

The term “innovation” is often thought of as equivalent to “technological revolution.” However, introducing a new product or service to the market does not constitute innovation unless it is consequently of substantial value to society. We, in the Fujifilm Group, strive to create innovative products and services that are valued by society through helping enhance quality of life. This is indeed the fundamental goal of our R&D activities.

The rapidly expanding research fields targeted by our R&D activities include: imaging and printing technology, which is indispensable for high quality communication via images and documentation; highly functional materials which contribute to the development of advanced information and communications technology (ICT) in society; and healthcare technology which supports our aesthetic and physical well-being. We aim to innovate in all these fields by applying the core technologies that we have established over many years of experience and that we are dedicated to enhancing day by day. Through such R&D activities, the Fujifilm Group will continue to create eco-friendly sustainable technologies to be the future foundation for saving our precious resources, energy efficiency, environment purification, and raising of living standards, and by so doing, we aim to achieve true improvements in the quality of life.

The R&D activities of the Fujifilm Group cover a very wide range of technologies and businesses, as is clear from the themes of the articles in this research report. The Fujifilm Group is committed to R&D activities that strive to truly “lead the way into the future for our fellow man and the earth,” working on behalf of mankind, our social activities, and the environment.
Development of Functional Cosmetics “ASTALIFT JELLY AQUARYSTA”
............ Tomoko TASHIRO, Akina NAKAUNE, Takuji KOSUGI, Jun ARAKAWA, Hisahiro MORI, Shinichiro SERIZAWA, Keichi SUZUKI, Fuyuhiko MORI, Atsushi ORIKASA, and Yoshisada NAKAMURA .... 1
Development of FUJI DRI-CHEM v-LIP-P Slide that Has the High Specificity to Pancreatic Lipase
............ Kentaro NAKAMURA, Shigeki KAGEYAMA, Hideaki TANAKA, Kazuya KAWASAKI, and Kaoru TERASHIMA .... 5
Development of “CALNEO C”, the Light-weight DR Cassette Compatible with Conventional Cassette
............ Tetsuya TANAKA, Jun ENOMOTO, Toshiyuki NABETA, Fusoshi YOSHIDA, Yasufumi ODA, and Makoto KITADA .... 12
Development of Environmentally Friendly Thermal CTP System “ECONEX”............... Norio AOSHIMA and Toshihiro WATANABE .... 17
Two-photon Sensitized Recording Materials for Multi-layer Optical Disk.
........................................ Masaharu AKIBA, Eri GOTO-TAKAHASHI, Hiroo TAKIZAWA, Toshio SASAKI, Hidehiro MOCHIZUKI, Tatsuo MIKAMI, and Toshiyuki KITAHARA .... 21
Development of the Server-side Web Browser for Mobile Phone based on the Imaging Technology “GT-Browser”
............................................................ Kentaro WATANABE, Takashi MIYAMOTO, Tetsuya SAWANO, Arito ASAI, and Norihisa HANEDA .... 25
Application of Hypothesis Verification to Software Development for Photo Products
............................................................ Tetsuya MATSUMOTO, Kei YAMAI, Kazuma TSUKAGOSHI, and Toshio MATSUBARA .... 28
Introduction and Practice of Statistical Project Management Technique in Software Development
............................................................................................... Masashi AISO*, Kouki YUASA*, and Keiichi SUZUKI .... 32
Next Generation of Digital Motion Picture Making Procedure: The Technological Contribution for Standardization of AMPAS-IIIF
............................................................................................................................................. Yasuharu IWAKI and Mitsuhiro UCHIDA .... 37
Visualization of Our Environmentally Conscious Activity by Implementation of Carbon Footprint Index to FUJIFILM Pre-Sensitized Plates
............................................................................................................................ Katsuyoshi ASAKURA, Naoki YOSHIKAWA, and Yoshiko OONUKI .... 42

* Co-researcher outside FUJIFILM Corporation
Development of Functional Cosmetics “ASTALIFT JELLY AQUARYSTA”


Abstract

The stratum corneum is the outermost layer of the skin and serves as a barrier to suppress loss of moisture and protects the body against the hazardous external substances such as viruses and allergens. It is well known that ceramides, one of the components of intercellular lipids in the stratum corneum, are gradually lost with aging. As a potent countermeasure to the decrease of ceramides, we mobilized our propriety NANO FOCUS TECNOLOGY to nano-disperse human-type ceramides down to 20 nm in diameter. The human-type nano ceramide dispersion exhibits permeability up to 9 times greater than that of precedent examples. Based on this invention, we have developed “ASTALIFT JELLY AQUARYSTA” that features the nano ceramide dispersion, for the purpose of improving barrier functions of the skin.

1. Introduction

We have been developing functional cosmetics by applying our technologies for “making beautiful pictures” to those for “making the beautiful skins”. The “ASTALIFT” is a basic skin care series developed by focusing on anti-aging for women since the late thirties. Bland concept of the “ASTALIFT” is “total collagen care” by using astaxanthin and 3 types of collagens.

“JELLY AQUARYSTA” (Fig. 1), a special care product in the ASTALIFT series, launched in September 2010, was developed with a goal of fundamental amelioration of the drying of the skin. While it has been said that aging of the skin is attributable primarily to “photo-aging” due to ultraviolet light or active oxygen, it has been known that inflammation caused by active oxygen is accelerated by drying of the skin. Accordingly, it is a matter of great importance for anti-aging to keep the skin fresh and moist.

2. Barrier Functions of the Skin

The skin is composed of the epidermis, dermis and subcutaneous tissue from its surface toward the inside. Epidermis consists mainly of keratinocytes. Keratinocytes generated newly by cell division in the basal stratum undergo differentiation and induction gradually to change their configurations and functions, and then, they are pressed up by keratinocytes generated subsequently to move to the surface of skin.

Cells denucleated in the final stage of differentiation are referred to as corneocytes. During differentiation to corneocytes, they release some lipids around them to form intercellular lipids. The layer consisting of the corneocytes and the intercellular lipids which fill gaps among the cells is referred to as the stratum corneum (Fig. 2).
2.1 Structure and Function of the Stratum Corneum

The stratum corneum, that is, the outermost layer of the skin, has a structure which is compared with one consisting of bricks (corneocytes) and mortar (the intercellular lipids). The layer serves as a barrier to suppress transepidermal loss of moisture and protects the body against external foreign bodies and stimuli.

The intercellular lipids corresponding to mortar consist of ceramides primarily (about 50%) and other lipids such as cholesterol and fatty acids. The ceramide forms a characteristic layered structure (lamellar structure) in which hydrophobic and hydrophilic domains are folded alternately. This lamellar structure provides the stratum corneum with strong barrier functions (Fig. 3)\(^1\).

![Fig. 3 Functions of stratum corneum.](image)

2.2 Roles of Ceramides

It has been known that amounts of ceramides in the stratum corneum decrease with age\(^2\). If the amounts of ceramides decrease, it would become difficult to form a well ordered lamella structure which would be important for the barrier functions. Therefore, loss of ceramides may result in drying or inflammation of the skin.

3. Nano-dispersion of Human-type Ceramides

In order to supplement ceramides decreased with age and to regain the original barrier functions of the skin, we developed Nano-dispersion of human-type ceramides with high permeability into the stratum corneum.

3.1 Types and Properties of Ceramides

Ceramides in the stratum corneum are synthesized from L-serine and palmitoyl-CoA by the actions of a variety of enzymes in the stratum spinous or granular layer of the epidermis. After stored once as glycosylceramides or sphingomyelin, those synthesized ceramides are excreted extracellularly from the lowermost layer of the stratum corneum. Then, those extracellular ceramides are converted to ceramides again enzymatically to form the lamella structure\(^3\).

Ceramides biosynthesized from L-serine in the stratum corneum are optically-active substances, while eleven types of structures are identified as basic skeletons. Ceramides with the same structures as those of ceramides in the stratum corneum are referred to as human-type ceramides (Fig. 4). Since transepidermal loss of moisture from the skin can be suppressed by applying the human-type ceramides to the skin, studies to treat patients with atopic dermatitis have been conducted with such ceramides\(^3\).

It was difficult, however, to mix the human-type ceramides in cosmetics because of their low solubilities in water or oils due to their easy crystallization. Therefore, precedent cosmetics, often made use of ceramides with higher solubility, such as pseudo-ceramides, structural analogues of human type of ceramides, or glycosylceramides, precursors of ceramides in the stratum corneum. Nevertheless, these ceramides did not recovery the barrier functions of the stratum corneum in a satisfactory level.

![Fig. 4 Molecular structure of human-type ceramide.](image)

3.2 Human-type Nano Ceramides by using NANO FOCUS TECHNOLOGY

By taking advantage of our original NANO FOCUS TECHNOLOGY, we have succeeded in dispersing the human-type ceramides into nanoparticles in water without using solubilizing oils. We could prepare a transparent dispersion of particles with a mean diameter of 20 nm and a narrow size distribution. Moreover, transmission electron microscopy revealed that the solution has finer particles as compared with those found in the precedent dispersion (Fig. 5). The dispersion of ceramides prepared by NANO FOCUS TECHNOLOGY is referred to as the human-type nano ceramides.
3.3 Effects on the Skin

For demonstrating superior performance of the human-type nano ceramides on the skin, their permeation properties into the stratum corneum were assessed. Each of the human-type nano ceramides and its reference was applied on the skin of the medial side of arms in 5 healthy subjects for 7 days. Permeated amounts of ceramide were determined by the tape-stripping method after the end of application. It was demonstrated that permeability of human-type nano ceramides was 9 times greater than that of its reference (Fig. 6).

In addition, we succeeded in visualizing the differences in permeation between the human-type nano ceramides and its reference by using a three-dimensional skin model (a dermal model). Ceramides was detected with the use of anti-ceramide antibody and the fluorescent antibody method. While ceramides can be identified as green fluorescence images as shown in Fig. 7, it was confirmed that the human-type nano ceramides (right picture) are distributed in wider area of the stratum corneum as compared with the its reference (left picture).

Another test was conducted to compare how much recovery of the barrier functions in the stratum corneum is possible by application of the human-type nano ceramides or its reference. In 14 healthy adult subjects, skin on the medial side of arms was damaged by removing fats with an acetone-ether mixture.

Then, the same amounts of the human-type nano ceramides and its reference were applied on the damaged skins every day to follow up the recovery of the barrier functions as evaluated by the transepidermal water loss (TEWL). Fig. 8 clearly shows that the treatment with human-type nano ceramides allows in faster recovery of the barrier functions in the affected area as compared with the its reference.

4. JELLY AQUARISTA

JELLY AQUARISTA contains high concentration of the human-type nano ceramides, which was developed under the concept of “leading to the flesh and moist skins by eliminating the origin of skin drying”.

4.1 Gel-type formulation

For mixing high concentrations of the human-type nano ceramides in cosmetics, we selected a gel-type formulation. Since this gel-type formulation contains cross-linkage of materials via a weak interaction, it prevents precipitation of the highly crystalline human-type ceramides and enables mixing them in high concentrations.

In addition, this weakly gel-type formulation provides particular physical property, where the material deforms when touched but its surface flat after 1 - 2 min (Fig. 9). Due to such a physical property, it became possible to provide characteristic usability of a cosmetic product, with which one can take care of one’s complexion with a fresh feeling every time.
4.2 Effects on the Skin

An 8 week continuous treatment study was conducted with JELLY AQUARISTA contains a high concentration of the human-type nano ceramides for the recovery of the barrier function of the skin. Ten female subjects used JELLY AQUARISTA for skin care every morning and night in addition to the usual skin care and their skin conditions were assessed before and after the treatment and in 2, 4 and 8 weeks. While moisture contents of skins are provided in Fig. 10, mean scores of texture, pore and wrinkle are shown in Fig. 11. It was demonstrated that post-treatment scores of moisture contents, texture, pore and wrinkle are improved significantly as compared with pre-treatment scores.

5. Conclusion

“ASTALIFT” is a series of functional skin care products developed by applying emulsification and dispersion technologies (NANO FOCUS TECHNOLOGY) including the human-type nano ceramides reported in the present article, which has been accumulated through the development of photograph films. The products have characteristic components including the nano emulsion of astaxanthin having potent antioxidizing activity and a combination of multiple types of collagens with different molecular weights and roles. We will continuously develop characteristic technologies for cosmetics to achieve fundamental amelioration of the skin.

References


(In this paper, “ASTALIFT”, “AQUARYSTA” and “NANO FOCUS” are the registered trademarks of FUJIFILM Corporation.)
Development of FUJI DRI-CHEM v-LIP-P Slide that Has the High Specificity to Pancreatic Lipase

Kentaro NAKAMURA*, Shigeki KAGEYAMA*, Hideaki TANAKA**, Kazuya KAWASAKI*, and Kaoru TERASHIMA*

Abstract

The lipase of blood is mainly a deviation enzyme from pancreas, and its activity is a highly evaluated index for pancreatitis diagnosis in human medical care. However, the sensitivity and specificity for the pancreatitis of the blood lipase activity is low in the veterinary medical care for dogs and cats, and making rapid diagnosis has been difficult to conduct. The Pancreatic Lipase Immunoreactivity (PLI), a blood diagnosis method, is the most superior in sensitivity and specificity as a pancreatitis marker for the dogs and cats at present. However, because PLI is not easy and rapid, there is a strong need for the development of an easy and rapid method of pancreatitis screening. FUJI DRI-CHEM (FDC), a dry chemistry method, is a system that enables measurement of various enzymic activities in the blood easily and rapidly, which has widely been used in veterinary care. Now we have developed the FDC v-LIP-P Slide having high specificity to measurable pancreas lipase. The measurement principle we used is the triglyceride method. The specificity for the pancreas lipase has also been improved by prescribing colipase, bile salt and sodium dodecyl benzene sulphonate, which is an anionic detergent. In addition, the reactivity has been improved by prescribing triolein, an emulsified substrate, to secure the area of the oil-water interface for the reaction to the pancreatic lipase. It was confirmed that the correlation of FDC v-LIP-P Slide and PLI was excellent. This shows that this slide is a very effective diagnostic product for the rapid screening of pancreatitis.

1. Introduction

While blood lipase as well as amylase and trypsin are deviation enzymes from pancreas, blood lipase and amylase activities increase significantly in patients with acute pancreatitis. It is known that lipase activity is more specific to pancreas and reflects pancreatic functions more specifically than amylase activity does, suggesting that increased lipase activity is a highly evaluated index for diagnosing pancreatitis1). While the mainstream of reagents for determining the blood lipase activity is the coupled enzyme method, wet chemistry methods include the 1,2-diglyceride substrate method developed by Asahi Kasei Corporation and dry chemistry methods include the diacetinase method developed by Eastman Kodak Company.

On the other hand, unlike humans, it has been demonstrated that the sensitivity and specificity for pancreatitis of the blood lipase activity determined by antecedent reagents are low in the veterinary medical care including diagnosis of pancreatitis in dogs and cats, and it has been known that rapid diagnosis of pancreatitis is difficult in these animals. As the reasons, it is considered that totaled activities of multiple different types of lipases would be evaluated because there are many lipase isozymes other than the pancreatic lipase including gastric lipase, hepatic lipase or lipoprotein lipase in blood of these animals.

Hence, Steiner et al. of A&M University of Texas developed the pancreatic lipase immunoreactivity (PLI) diagnosis method by using an antibody which binds specifically to the pancreatic lipase only and reported that the method is effective for diagnosing pancreatitis. At present, the PLI method is considered to be the most superior pancreatitis marker in sensitivity and specificity for dogs and cats2), 3).

Nevertheless, the method as only one blood diagnosis method at present for pancreatitis in dogs and cats is not an easy and rapid procedure with taking a few days to get measurement results. Because such disadvantages of the method do not lead to rapid diagnosis, there is a strong need for developing an easy and rapid method for screening pancreatitis.

Reportedly, the DGGR substrate method, a reagent for determining the blood lipase activity (a wet chemistry
method) which was developed by Roche Diagnostics and has becoming common recently, has higher specificity for detection of canine pancreatic lipase activity and is more useful as a method to determine the enzyme activity as compared with the 1,2-diglyceride substrate method which had ever been the mainstream of those diagnosis methods\(^5\). It indicates presumably that specific measurement of the pancreatic lipase activity can be achieved by using different substrates, different aids and different conditions of the reaction.

FUJI DRI-CHM (hereinafter, referred to as FDC) as a dry chemistry method is an easy and rapid assay system to determine a variety of enzyme activities in blood and has been extensively used now in the veterinary medical care. Hence, we conducted a study to develop an assay method with high specificity for the pancreatic lipase activity in order to address the needs for diagnosing pancreatitis. The present report refers to the results of the study.

2. Points of Development

2.1 Determination of Measurement Principle to be Adopted for Preparation of Slides

2.1.1 Selection of Measurement Principle

While there are a variety of methods for determining lipase activity, those listed in Table 1 below provide the representative colorimetric methods which use visible lights applicable to the FDC analyzer. From various studies conducted hitherto, it has been reported that the 1,2-diglyceride substrate method\(^5\), \(^6\) as well as the diacetinase method\(^7\) have low specificities for the pancreatic lipase. By contrast, the DGGR substrate method has been reported to have high specificity\(^8\). Additionally, methods to use triglyceride, a natural substrate of the pancreatic lipase, have been reported to have higher specificity for the pancreatic lipase as compared to that to the lipoprotein lipase or the hepatic lipase\(^8\). Accordingly, the DGGR substrate method and the triglyceride method were chosen for selection of measurement principle and evaluation was performed for preparation of dry chemistry methods.

### Table 1 The list of the lipase measurement principles.

<table>
<thead>
<tr>
<th>Name of method</th>
<th>Maker developed the method</th>
<th>Assay method</th>
<th>Specificity for pancreatitis</th>
<th>Maker adopted the method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diacetinase method (a dry chemistry method)</td>
<td>EK</td>
<td>Coupled enzyme method</td>
<td>Positive reactions may occur also for diseases other than pancreatitis(^7). Ortho Clinical Diagnostics IDEXX Laboratories (exclusive use for animals).</td>
<td>Several domestic companies including Wako Pure Chemicals Industries No.1 share in pharmaceutical market for humans and animals.</td>
</tr>
<tr>
<td>1,2-Diglyceride substrate method (a wet chemistry method)</td>
<td>Asahi Kasei</td>
<td>Coupled enzyme method</td>
<td>Low specificity for canine pancreatitis, and increased lipase activity is observed in heparin-added plasma.</td>
<td>Roche Diagnostics, Kyowa Medex Co. No.2 share in pharmaceutical market for humans.</td>
</tr>
<tr>
<td>DGGR substrate method (a wet chemistry method)</td>
<td>Roche Diagnostics</td>
<td>Resorufin substrate method</td>
<td>High specificity for human and canine pancreatitis(^8).</td>
<td>Roche Diagnostics, Kyowa Medex Co. No.2 share in pharmaceutical market for humans.</td>
</tr>
<tr>
<td>Triglyceride method (a wet chemistry method/a dry chemistry method)</td>
<td>Asahi Kasei</td>
<td>Coupled enzyme method</td>
<td>Specificity of triglyceride for the pancreatic lipase is higher than that for hepatic lipase or LPL(^3).</td>
<td></td>
</tr>
</tbody>
</table>

2.1.2 Assessment of Feasibilities of the DGGR Substrate Method and the Triglyceride Method as Dry Chemistry Methods

The DGGR substrate assay is a method to use 1,2-O-dilauryl-rac-glycero-3-glutaric acid-(6'-methylresorufin)-ester as a substrate. The substrate is decomposed by lipase under the alkaline conditions to form 1,2-O-dilauryl-rac-glycerol and an unstable intermediate, glutaric acid-(6'-methylresorufin)-ester. Under the alkaline conditions, the latter is decomposed spontaneously to form glutaric acid and methylresorufin with an absorption peak at around 580 nm (Fig. 1). The DGGR substrate assay is a method to measure the rate of increase in absorbance of red color of methylresorufin\(^5\). Namely, the substrate used for the DGGR substrate method is very unstable, and hence, its temporal stability was concerned. A substrate DGGR could be dispersed in liquids at slightly acidic pH and was stable for a year in the refrigerator. On the other hand, it was demonstrated that the substrate was easily decomposed at neutral pH and its decomposition rate was accelerated under the slightly alkaline conditions (pH=8; the optimum pH for lipase) or in the presence of sodium deoxycholate, an activator of lipase. By NMR and MASS analyzes of decomposition mechanisms of the substrate, it was identified that the ester bond (indicated by an arrow in Fig. 1) adjacent to the chromophore preferentially among 2 ester bonds was preferentially decomposed.

![Fig. 1 Reaction scheme of the DGGR method.](image-url)
In wet chemistry methods, a substrate unstable against some pH would be stored before using in solutions under the pH conditions where it is stable. Upon analysis by an autoanalyzer, it would be mixed with another reaction reagent at pH 8 which is the optimal pH for lipase to enable a measurement of lipase activity. By contrast, in case of the FDC slide, all reagents necessary for measurement of lipase activity have to be packed onto the slide as described in section 2.3. Accordingly, it has to contain buffering agents and alkaline components necessary for preparing an environment at pH 8 in addition to reaction reagents. It would be very difficult to store DGGR as a substrate in the slide under such conditions.

In contrast, in the case of the FDC slide prepared by using triglyceride as a substrate, it was demonstrated that there was no change in its reactivity in a 2- or 3 week accelerated stability test at 45°C even at pH 8, suggesting its extremely higher stability as compared with DGGR.

Based on the above results, it was determined that development of a dry chemistry method would be conducted for the triglyceride method.

2.2 Study on Improvement of Reactivity and Specificity of the Pancreatic Lipase

2.2.1 Reaction Mechanism of the Pancreatic Lipase

One of the enzymatic properties of the pancreatic lipase is that the enzyme requires colipase, a protein with a molecular weight of 11kDa, for its efficient enzymatic activity. Colipase is secreted from pancreas as procolipase which is then transformed to active colipase by the action of trypsin in the intestinal lumen for binding to lipase. The pancreatic lipase is also characterized by another property distinctly different from those of other esterases, that is, it exerts its high enzymatic activity only after an interface is formed between fatty acid esters and the water layer. Accordingly, the lipase activity would be influenced by the presence of such substances as bile salt which affect on the emulsion formation.

The unique properties of the pancreatic lipase are considered attributable to its characteristic structure referred to as “a lid” domain which covers the active center of this enzyme. It is considered that, by ordinary, the “lid” is closed and its enzymatic activity is only modest when it stands alone. However, its conformation changes in the presence of colipase and bile salt and its active center would be exposed as shown in Fig. 2. Then, the hydrophobic domain of the active center binds to substrates stably to exert enzymatic activity. Under the physiological conditions, the pancreatic lipase is considered to form such a complex with colipase, bile salt and lipids for digesting fats.

Since a combined formulation of bile salt and colipase has been used also for the DGGR substrate method with high specificity for the pancreatic lipase, formulation of the dry chemistry method was designed based on such a formulation.

2.2.2 Study on Formulations for the Dry Chemistry Method with High Specificity for the Pancreatic Lipase

Study on formulations was performed with the use of triolein as a reaction substrate and furthermore, by using colipase and bile salt. While sodium deoxycholate was used mainly as bile salt, a combined formulation of sodium deoxycholate and water soluble sodium taurodeoxycholate was used because water solubility of the former was not so high. In addition, various reagents were formulated to achieve the following reaction scheme because the measurement principle of this assay was the coupled enzyme method (Fig. 3).

![Fig. 2 Schematic view of the reaction of the pancreas lipase.](image)

![Fig. 3 Reaction scheme of the FDC v-LIP-P Slide.](image)

In canine samples, was demonstrated a correlation of the FDC slide prepared according to the above formulation and the DGGR substrate method.

While these 2 methods correlated relatively well with each other [correlation coefficient (r) = 0.930], there were separations of some data at the lower lipase concentration range among those provided by the FDC slide and especially those obtained by the DGGR substrate method [LiquiTech Lipase Color II (Roche Diagnostics), hereinafter, referred to
as the DGGR substrate method) (Fig. 4a).

Separations of those data observed in the lower lipase concentration range were considered attributable to insufficient formation of an interface between fatty acid esters and the water layer where lipase exerts its activity. Accordingly, effects of addition of a detergent were assessed in order to provide a better oil-water interface as the reaction field for lipase. A point to consider for selecting a detergent is to find out a detergent that does not affect the reactivity of lipases other than the pancreatic lipase. On the contrary, anionic detergents including sodium dodecyl sulfate are known to inhibit the activity of lipases other than the pancreatic lipase. 13), 14), 15). In results of assessments conducted based on these reports, sodium dodecyl benzene sulfonate among anionic detergents was found to elevate the activity of the pancreatic lipase without changing the activity of lipases other than the pancreatic lipase. In the assessment of a correlation between above 2 methods performed with the same canine sample as that used in the aforementioned test, improvement was observed in the lower lipase concentration range with very good correlation coefficient [(r)=0.977] being observed (Fig. 4b).

Reactivities of the FDC slides containing the dissolved type of triolein and the emulsified type of triolein were assessed for the control sample of the pancreatic lipase with high activity (800 U/L) and that with low activity (40 U/L) to compare the reaction rates provided by using these different states of substrate. In result, it was demonstrated that reactivity for the pancreatic lipase of the FDC slide containing the emulsified type of substrate is approximate 30% higher than that containing the dissolved type of substrate (Table 2).

Based on the above results, the method was selected to apply and dry the emulsions of triolein prepared in advance for preparing the FDC slide (a dry chemistry method).

**Table 2**  Reactivity comparison by difference of state of substrate (triolein) in FDC v-LIP-P Slide.

<table>
<thead>
<tr>
<th></th>
<th>Dissolved type</th>
<th>Emulsified type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference in reaction rate ((\triangle OD_r/min))</td>
<td>0.07</td>
<td>0.091</td>
</tr>
<tr>
<td>Percent difference in reaction rate of emulsified type relative to that of dissolved type</td>
<td>100%</td>
<td>130%</td>
</tr>
</tbody>
</table>

**2.3 Structure of the FDC Slide**

The structure of the FDC v-LIP-P slide is shown in Fig. 5.

The FDC v-LIP-P slide is composed of 2 layers including a reagent layer and a spreading layer set on a transparent support film made of polyethylene terephthalate. While the reagent layer consists of coupled enzymes which react with glycerin generated in the spreading layer and color forming dyes, the spreading layer contains triolein emulsion which is a substrate of the pancreatic lipase, colipase and bile acid lipase was assessed by developing a method to prepare emulsions of triolein in advance. For preparing triolein emulsions, sodium dodecyl benzene sulfonate was used as a detergent, while gelatin and polyvinyl pyrrolidone were used as protective colloids. Emulsification was performed with a high pressure emulsifier/disperser to prepare emulsions with a mean particle diameter of about 200 nm.

**Fig. 5** Structure of FDC v-LIP-P Slide.
necessary for expression of the pancreatic lipase activity, sodium dodecyl benzene sulfonate as a reaction aid and a coupled enzyme. When a test sample was applied on the FDC v-LIP-P Slide, it spreads uniformly in the spread layer to react with the substrate (triolein). 2-Monoglyceride generated by the action of lipase is decomposed by the monoglyceride lipase to form glycerol and fatty acid. Glycerol is converted to L-α-glycerophosphoric acid by the action of the glycerol kinase in the presence of ATP and Mg$^{2+}$. L-α-glycerophosphoric acid is oxidized by the action of the glycol-3-phosphate oxidase to generate hydrogen peroxide. By the action of peroxidase, hydrogen peroxide oxidizes diaryl imidazole type of leuco-pigment to generate a blue pigment. The rate of formation of this blue pigment is determined by measuring the changes in the reflected optical density at 650 nm from 3.0 min to 5.0 min which, then, would be converted to lipase activity by a calibration curve built in a dedicated instrument.

3. Confirmation of the Effectiveness of FDC v-LIP-P Slide

3.1 Confirmation of Specificity for the Pancreatic Lipase

In order to validate the effectiveness of FDC v-LIP-P slide developed this time, we confirmed a correlation of data generated by the FDC v-LIP-P slide and those generated by the PLI method (Spec cPL: IDEXX Laboratories, Inc., referred to as the PLI method), which is said to be only one effective blood diagnosis method of pancreatitis in dogs and cats. In addition, correlations of data were confirmed among those generated by the FDC v-LIP-P slide, the diacetinase method (VetTest Slide LIPA: IDEXX Laboratories, Inc., referred to as the diacetinase method) which is a conventional blood lipase assay method as a dry chemistry method, the 1,2-glyceride method (Lipase Color Auto Test Wako kit: Wako Pure Chemical Industries, referred to as the 1,2-glyceride method) and the DGGR substrate method as wet assay methods (Fig. 6).

A good correlation was observed between the FDC v-LIP-P Slide and the PLI method with a correlation coefficient ($r$) = 0.931. On the other hand, a low correlation was found between the diacetinase method, as another dry chemistry method and the PLI method, with a correlation coefficient ($r$) = 0.314.

With respect to wet chemistry methods, a good correlation was observed between the DGGR substrate method and the PLI method with a correlation coefficient ($r$) = 0.972, and it was confirmed that the pancreatic lipase could be measured specifically by this method as reported in articles. On the other hand, it was confirmed that the correlation coefficient ($r$) = 0.401 when a correlation between the 1,2-diglyceride method and the PLI method was assessed.

Based on these results, it is supposed that the FDC v-LIP-P Slide showing a good correlation with the PLI method is a method with high specificity for the pancreatic lipase similarly as the DGGR substrate method. By contrast, data provided by using the diacetinase method or the 1,2-diglyceride method showed low correlations with the PLI method were higher in many cases than the data obtained by the PLI method, especially in the case of test samples with low PLI value. Hence, it was suggested that lipase isozymes other than the pancreatic lipase may be measured by these 2 methods.

It is presumed that both of the DGGR substrate method and the FDC v-LIP-P slide show high specificity for the pancreatic lipase from the results that very good correlations were observed among these 2 methods and the PLI method by using canine test samples. Hence, a correlation was assessed between the DGGR substrate method and the FDC v-LIP-P Slide by using canine and feline test samples (Fig. 7a).

By using canine test samples, a very good correlation was observed between the DGGR substrate method and the FDC v-LIP-P slide with a correlation coefficient ($r$) = 0.993. Although the quantities of test samples with intermediate and high lipase content were limited in the case of feline samples, a good correlation was observed between the DGGR substrate method and the FDC v-LIP-P slide with a correlation coefficient ($r$) = 0.983 (Fig. 7b).
As for feline test sample, correlations have not been confirmed between the PLI method and the FDC v-LIP-P Slide or the DGGR substrate method. Moreover, further studies would be needed on specificity of these methods for the pancreatic lipase, since sufficient quantities of test samples with intermediate and high lipase content were not subjected to the assessment. It was supposed, however, that isozymes other than the pancreatic lipase would not be measured by these methods because a high correlation was observed between these 2 methods.

### 3.2 Confirmation of Simultaneous Reproducibility

In order to assess whether the degree of variation of data provided by repeated assays with the FDC v-LIP-P slide is in the acceptable range, simultaneous reproducibility assays were conducted. In Table 3, are provided the results of assays performed 20 times repeatedly for each of 3 canine serum samples with different lipase activities. Since a coefficient of variation (CV) as a measure of variation was lower than 4% at each activity level, it was confirmed that the reproducibility of assay with the FDC v-LIP-P slide was in the acceptable range for diagnosis of pancreatitis.

**Table 3** Reproducibility in measurement with FDC v-LIP-P Slide for dog serums.

<table>
<thead>
<tr>
<th>dog serum 1</th>
<th>dog serum 2</th>
<th>dog serum 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37</td>
<td>678</td>
</tr>
<tr>
<td>2</td>
<td>36</td>
<td>706</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>671</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
<td>707</td>
</tr>
<tr>
<td>5</td>
<td>37</td>
<td>723</td>
</tr>
<tr>
<td>6</td>
<td>37</td>
<td>686</td>
</tr>
<tr>
<td>7</td>
<td>38</td>
<td>719</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>680</td>
</tr>
<tr>
<td>9</td>
<td>36</td>
<td>695</td>
</tr>
<tr>
<td>10</td>
<td>37</td>
<td>713</td>
</tr>
<tr>
<td>11</td>
<td>37</td>
<td>725</td>
</tr>
<tr>
<td>12</td>
<td>35</td>
<td>700</td>
</tr>
<tr>
<td>13</td>
<td>35</td>
<td>722</td>
</tr>
<tr>
<td>14</td>
<td>34</td>
<td>749</td>
</tr>
<tr>
<td>15</td>
<td>38</td>
<td>730</td>
</tr>
<tr>
<td>16</td>
<td>34</td>
<td>704</td>
</tr>
<tr>
<td>17</td>
<td>36</td>
<td>708</td>
</tr>
<tr>
<td>18</td>
<td>36</td>
<td>683</td>
</tr>
<tr>
<td>19</td>
<td>37</td>
<td>676</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
<td>685</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average (U/L)</th>
<th>SD (U/L)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36.5</td>
<td>1.47</td>
<td>4.0</td>
</tr>
<tr>
<td>703.0</td>
<td>21.1</td>
<td>3.0</td>
</tr>
<tr>
<td>393.0</td>
<td>9.0</td>
<td>2.3</td>
</tr>
</tbody>
</table>

### 4. Conclusion

We assessed FDC v-LIP-P slide that was developed for enabling rapid and easy screening of pancreatitis in the veterinarian medical care.

The DGGR substrate method or the triglyceride method is suitable for screening of pancreatitis as a measurement principle because these methods have high specificity for the pancreatic lipase. 1,2-O-dilauryl-rac-glycero-3-glutaric acid-(6'-methylresorufin)-ester, a substrate to be used for the DGGR method, is very degradable and unstable at pH 8, i.e. optimum pH for the pancreatic lipase, whereas triolein, a substrate of the triglyceride method, is stable at pH 8.0. In the case of the FDC slide, it has to contain all reagents necessary for measurement of lipase activity. Since triolein, a substrate of the triglyceride method, was stable at pH 8, i.e. under its storage condition, it was considered applicable as a substrate of a dry chemistry method and the triglyceride method was selected as the measurement principle.

To secure specificity for the pancreatic lipase, sodium dodecyl benzene sulfonate was prescribed in addition to colipase and bile salt. By prescribing these materials, a good correlation could be achieved in canine test samples.

In addition, improvement of reactivity of the method for the pancreatic lipase could be attained by emulsifying and dispersing triolein, a substrate, and by prescribing the emulsified substrate on the slide.

A very good correlation was observed between the PLI method and the FDC v-LIP-P slide, into which the above measures were introduced, with the use of canine test samples. A very good correlation was observed additionally between the FDC v-LIP-P slide and the DGGR method, which showed also a very good correlation with the PLI method. It was also confirmed that the degree of variation of data provided by the FDC method was in the acceptable range.

The PLI method, only one effective diagnosis method that is said to be available today for pancreatitis in dogs and cats, is not an easy and rapid procedure with taking a few days to get measurement results and has a disadvantage that it do not lead to rapid diagnosis. Since the FDC v-LIP-P Slide that was developed this time has high specificity for the pancreatic lipase and can be packed onto the easy and rapid FDC system which has been used hitherto in the veterinarian medical care, the slide is expected to be a very effective diagnostic product for pancreatitis in the veterinarian medical care.

### 5. Acknowledgment

The authors express their deep gratitude to Mr. Jun Arakawa of Pharmaceutical & Healthcare Research Laboratories for his cooperation for assessing substrates and subsequent manufacturing/introducing an emulsifier. The authors are also grateful to everybody of FUJIFILM Medical Co., Ltd. who kindly provided us with animal samples.
References


(In this paper, “VetTest” is a registrated trademark of IDEXX Laboratories, Inc. “FUJI” and “DRI-CHEM” are the registered trademarks of FUJIFILM Corporation.)
Development of “CALNEO C”, the Light-weight DR Cassette Compatible with Conventional Cassette

Tetsuya TANAKA*, Jun ENOMOTO*, Toshiyuki NABETA*, Futoshi YOSHIDA*, Yasufumi ODA*, and Makoto KITADA*

Abstract

We have developed a new digital radiography system FUJIFILM DR CALNEO C, of 384 × 460 mm in size and 14mm thick, equivalent to a CR (Computed Radiography) cassette. The other main features are the light-weight of 2.8 kg and high quality images with low dose. Since CALNEO C is the same size as a CR cassette, it can be set to an existing X-Ray Table and Stand. The 2.8 kg case having a light carbon & resin frame provides a user-friendly workflow to technologists. DQE (Detective Quantum Efficiency) of the “Irradiation Side Sampling (ISS) method” FPD (Flat Panel Detector) shows a 1.7 times higher level than our existing model of FCR VELOCITY.

1. Introduction

We have been engaged in the development of all aspects of diagnostic X-ray modalities, which have evolved from Screen-Film (S/F) systems to FCR (Fuji Computed Radiography) and then to DR (Digital Radiography), and have been working on image quality improvement (lowering radiation dosage), diagnostic performance enhancement, and improvement of the workflow in X-ray examination rooms. For DR systems, we launched in April 2010 our new cassette digital radiography system “FUJIFILM DR CALNEO C”. In this system, we achieved higher image quality by adopting the ISS (irradiation side sampling) method for the X-ray Flat Panel Detector (FPD, hereafter), where the X-ray sensor is placed on the side opposite to that of the conventional detector, and the cassette size is compatible with the conventional CR cassettes and hence can be retrofitted. This system is a high image quality, high throughput cassette digital radiography system launched with an aim to replace the existing FCR/CR systems, with the DQE (detective quantum efficiency) about 1.7 times better than the conventional FCR systems, and with the capability to be retrofitted to the X-ray tables and stands already installed in hospitals. Using the technology we developed for the cases of CR cassettes as motifs, we realized a lightweight cassette case for this DR system, which enables an easy workflow with its excellent handling capability and which when operated give the same impression as the former FCR systems. In this report, we discuss the development of this light-weight cassette case, the image quality improvement technology for FPD, and the system features and performances of FUJIFILM DR CALNEO C (model type : DR-ID 600).

Fig. 1 FUJIFILM DR CALNEO C.

2. Development of a Light-weight Cassette Case for FPD Panel

2.1 Overview of the Case Structure

In CALNEO C, we succeeded in balancing very light weight, about 2.8 kg, with sufficient strength by adopting a modified version of the flexible structure case we designed for CR cassettes. We also succeeded in achieving high image quality by avoiding shielding of more X-rays than necessary, which we achieved by implementing a thermal diffusion structure and a noise shielding structure using minimal structural components.

2.2 Cassette Case Weight Reduction

There are two possible usage configurations of the DR cassette: one is the conventional imaging with the panel
installed on an imaging stand in the upright or horizontal position, and the other is freely positioned imaging where the panel is placed directly in contact with the patient. In the case of freely positioned imaging, the radiologist needs to manipulate the DR cassette panel using only one hand, and therefore it is a prerequisite that the panel is sufficiently light. Moreover, in freely positioned imaging, the panel needs to have sufficient strength so that it can take the weight of the patient. Hence the biggest challenge in this development project was to achieve both strength and weight reduction.

In order to resolve this technical challenge, we took the following measures and succeeded in producing CALNEO C, that weighs only about 2.8 kg:

(1) The case: we optimized the strength of the “carbon board and resin frame” combination, which was successfully adopted for CR cassette, by adjusting the inserted frame and consequently the required total rigidity was achieved with minimum weight.

(2) The chassis: we empirically found a material that has no strength but yet has sufficient conductivity and noise shielding property. Structurally it consists of the lightest possible “thin metal sheet”.

(3) The other parts are made as small and light weight as possible by giving the cassette itself a “flexible structure” which allows changes in the overall shape of the cassette.

Fig. 2 shows the relation between the weight and the strength against falling impact of DR panels of different manufacturers. In CALNEO C, the balance between the weight and strength are ensured by grouping together all the parts as those contributing for strength and others, and minimizing the weight proportion of parts for strength, which is the major factor in determining the weight of the entire system.

Fig. 3 shows the simulated panel deformation at the point of falling impact, and the result of a falling experiment imaged with a high-speed camera. One can see that the entire cassette bends and absorbs the impact. The amount of deformation of the case is adjusted so that the TFT glass and the circuit board do not reach the breaking limit, by optimizing the rigidity of all portions of the case.

2.3 Heat Dissipation Design

Providing for heat dissipation of internal circuitry is an important factor for operational stability of DR cassette over an extended period of time. Temperature increase inside the cassette will change the characteristics of the charge amplifier and the TFT (thin film transistor) panel, resulting in unevenness or noise in the produced images.

A key to achieving internal heat dissipation is minimizing the temperature differences within the TFT panel or within each charge amplifier, while at the same time reducing the absolute temperatures of the internal parts.

The cooling mechanism of CALNEO C employs the following measures for equalizing the internal temperature and for reducing the absolute temperature:

(1) The case is structured so that the back cover (non-imaging side) is the main heat dissipating surface. The heat transfer pathway and the heat capacity have been optimized using thermal simulation so that the residual heat is minimized.

(2) The electronic chassis is composed of layers of metal sheets with high heat conductivity and heat insulating materials so that the heat is distributed, making the temperature within the TFT panel surface uniform.

Fig. 4 shows the temperature distribution inside the panel before and after applying the optimization measures described above. By introducing these optimizations we achieved a temperature distribution on the surface of $\Delta T < 3k$ and the absolute temperature of $t < 40^\circ C$. 
2.4 Noise Shielding Mechanism

A DR cassette has a structure that is very susceptible to external noise and statics because it consists of a TFT panel and a circuit board surrounded by a thin case. Therefore, we employed a shielding mechanism where each of the TFT devices and the circuit board is placed inside an enclosing shield of conducting material. The shielding parts are secured by screws or by caulking, and the outer periphery that may be opened for maintenance purposes is shielded completely by conducting gaskets.

With the structure described above, we could achieve sufficiently good performance to pass the EMC tests.

3. Improvement of FPD Image Quality

3.1 FPD Installed in CALNEO C

CALNEO C is installed with an “indirect conversion FPD”, which consists of a combination of a scintillator that converts X-ray to visible light, photodiodes that convert visible light to electric charge, and a TFT layer which is a readout circuit. An indirect conversion FPD has detection units composed of a scintillator and a photodiode detector that are integrated with the plane, making thinner and lighter systems possible. Conventional indirect conversion FPDs are built in the PSS (penetration side sampling) configuration, where the scintillator layer is placed on the side where X-rays strike the panel (the side toward the target), while the photodiode detector is placed on the side where the X-rays leave the panel. For the FPD of CALNEO C, our original “ISS method” is used instead, where the detector is placed on the side where the X-rays strike and the scintillator is placed on the reverse side (Fig. 5).

3.2 Features of the ISS Method and Comparison with the PSS Method

The possible approaches for improving image quality of indirect conversion FPDs include enhancing the X-ray absorption of the scintillator layer, increasing the efficiency of detection of the light generated by the X-rays, and designing the panel so that the diffusion of light is reduced to avoid blurring in images.

For enhancing X-ray absorption, increase in the thickness of the scintillator layer is effective, while for increasing the efficiency of detection of the generated light, minimization of the attenuation of the generated light before it reaches the detector is effective. The ISS method is a technology that provides improved image quality, developed by careful study of the detection mechanism of indirect conversion FPDs and applying the above two approaches at the same time.

Since the X-rays projected on the scintillator layer are absorbed and attenuate exponentially as they proceed inside the layer, the amount of luminescence is much greater on the side where the X-rays strike and smaller on the opposite side. Moreover, there is attenuation caused by the scintillator layer itself of this design because it is packed tightly with grains of fluorescent material and these grains cause scattering of light.

Fig. 6 shows the relation between the thickness of the scintillator layer and the sensitivity. In the case of the PSS configuration, when the layer thickness is increased with the purpose of enhancing the X-ray absorption, the effect of scattering becomes very large because the points in the scintillator layer with the maximum amount of luminescence are those farthest from the detector. On the other hand, in
the case of the ISS method, the point with the maximum luminescence is closest to the detector and there is no decrease in sensitivity due to the increase in layer thickness (Fig. 8 (a), (c)).

The luminescent light generated by entering X-rays has isotropic luminosity and is diffused inside the scintillator layer. Therefore, the farther from the detector the luminescence is generated, the more diffusion, resulting in blurring.

To summarize, the indirect conversion FPD with our new ISS configuration achieves higher image quality and higher resolution than conventional FPDs with the PSS configuration, and can greatly contribute to the image quality competitiveness of this type of product.

4. System Features of FUJIFILM DR CALNEO C

4.1 Image Quality Performance

Fig. 9 and Fig. 10 show the DQE and the MTF of CALNEO C and its predecessor FCR PROFECT CS. The applied radiation quality was RQA5 of the IEC standard, and the applied dose was 1mR. CALNEO C has about 1.7 times more DQE than that of FCR PROFECT CS, and the MTF of CALNEO C was about 1.25 times more. This means that by using CALNEO C it is possible to lower the radiation dosage while keeping the image quality equivalent to or better than the previous devices.
4.2 High Throughput

We succeeded in enhancing the throughput of CALNEO C almost as high as that of built-in CALNEO by applying measures for residual image reduction and for fast readout. This allows for establishment of a workflow for institutions that does not undergo strain even with frequent imaging use.

4.3 Compatibility with FCR

For image data handling in CALNEO C, we adopted log data instead of the linear data which is normally used with DR, which makes it possible to use the image processing engine that we developed for FCR as is. This makes the procedures for CALNEO C images similar to those developed for our existing systems, allowing stable image processing and reduction of work for radiologists. Moreover, since it is possible to produce images using the same console as FCR systems, in institutions where FCR systems are installed alongside, the technologists can input patient information and carry out post imaging operations using a single console, which allows efficient workflow.

5. Conclusion

In this article, we gave an overview of the technology for the cassette case, the image quality enhancement technique, image features, and the system performance of our newly developed FUJIFILM DR CALNEO C. We expect that this system and related technologies, which contribute to the reduction of radiation dosage and improvement of workflow, will be chosen by many customers.

We hope to continue the quest for new technology and for more cost effective systems so that we can further contribute to the improvement of the quality of medical services and the enhancement of people's quality of life.

References


(In this paper, “CALNEO”, “FCR” and “FUJIFILM” are the registered trademarks of FUJIFILM Corporation.)
Development of Environmentally Friendly Thermal CTP System “ECONEX”

Norio AOSHIMA* and Toshihiro WATANABE*

Abstract

We have developed an environmentally friendly thermal CTP (Computer To Plate) system “ECONEX”, which is composed of a positive thermal CTP plate “XP-F”, developer/replenisher “XP-D/XP-DR”, apparatus for reducing waste developer “XR-2000, XR-5000”, and a CTP setter “Luxcel T-9900G CTP”. Rapid dispersion developing technology of XP-F, enabling a highly concentrated replenisher to be used, realized substantial reduction of replenisher usage. XR-2000 and XR-5000, which incorporate decompression distillation technology, realized an 85% reduction of waste developer/rinse water along with low energy consumption. A novel LED (Light Emitting Diode) array in “Luxcel T-9900G CTP”, characterized by a broad depth of focus and non-radiation waiting sequence, has demonstrated both high quality and energy saving. We expect the ECONEX system to contribute in promoting the ecology movement in the printing industry.

1. Introduction

The wave of the global environmental load reduction movement has reached the printing industry. For example, the Japan Federation of Printing Industries, which is an industry-wide organization in Japan, has operated an “green printing” certification system since 2001 with the aim of promoting usage of environmentally friendly CTP (computer to plate) systems and processless plates, and set up in 2009 a voluntary action plan for establishing a recycling society, which aims to reduce the amount of final disposal of industrial waste including developer waste by 24% from the level of 2005 by the year 2010.

The kind of waste generated during the processes by which our customers produce plates for printing (plate making processes) include prepress films, developer liquid waste, and various packing materials.

To deal with prepress film, thanks to the development of digital typesetting (DTP: desktop publishing) and progress in laser and printing plate production technology, use of the CTP system, where the platesetter can output images directly onto a printing plate without using prepress films, is rapidly widening. Thanks to the benefit of cost reduction due to this simplified printing process as well as the contribution to environmental load reduction, the proportion of printing done by CTP systems in the world is currently more than 50%, while in 2001 it was round 20%1).

Moreover, manufacturers of printing plates including Fujifilm are working on developing environmentally friendly CTP plate making systems, namely, systems for simplified processing of CTP plates and for processless CTP plates, which reduce the environmental load of developer waste. However, the printing quality of these systems is not as good as those by the conventional printing plate making systems that use strong alkaline developer. Therefore the key for these new systems to become more widely used is attaining more satisfactory image quality.

The waste from packaging materials include cardboard boxes for external packaging and interleaf paper and cardboard for internal packaging, and this paper waste can be sufficiently dealt with by existing recycling systems.

Given the situation above, we consider that it is also important to work on the reduction of environmental load generated by the high quality printing plate making systems that use strong alkaline developer, which are currently mainstream, and our R&D is pursuing this goal as well. In this article, we report on our effort for environmental load reduction of the positive thermal CTP system that has a share of more than 90% in the CTP market for commercial printing in Japan.

Original paper (Received December 3, 2010)

* Graphic Materials Research Laboratories
Research & Development Management Headquarters
FUJIFILM Corporation
Kawashiri, Yoshida-cho, Haibara-gun, Shizuoka
421-0396, Japan
2. The Structure of the ECONEX System and its Technical Features

We launched in 2010 our environmentally friendly thermal CTP system “ECONEX”. This is a system whose major components are the positive thermal plate “XP-F”, the developer waste reduction apparatus “XR-2000, XR-5000”, and the thermal CTP setter “Luxel T-9900G CTP”. The system has been received favorably in the market, as XP-F and XR-2000/5000 achieve substantial reduction in developer waste, and Luxel T-9900G CTP achieves high productivity while saving electricity.

2.1 CTP Plate “XP-F”

The development process of a positive thermal CTP plate consists of developing, rinsing and finishing (Fig. 1). In order to keep the resulting quality uniform, processing solutions are replenished according to the amount used in each process step. Any excess of solution caused by over-replenishment must be processed as industrial waste and becomes a waste of developing process solution. This means that by reducing the amount of solution replenishment, it is possible to reduce the amount of solutions that are wasted.

![Fig. 1 Developing process of positive thermal CTP plate.](image)

Among the above processes, an approach to replenishment reduction through developer solution can be made chiefly in the developing process. The two types of replenishment in the developing process are the processing replenishment whose amount is proportional to the surface area of the processed plate, and the time-dependent replenishment required due to the pH decrease caused by carbon dioxide in the atmosphere which dissolves into the developer solution as the time passes. The latter accounts for about 70% of replenishment required in the developing process. In order to reduce the amount of time-dependent replenishment, a development system is required that does not depend on the alkaline component (i.e., the pH level) of the developer solution. However, it is generally necessary to add to the developer solution some developing agent such as organic solvent to replace the alkaline component. Use of such organic solvent component, which is also called VOC (volatile organic compound), is problematic and does not qualify as an environmentally friendly solution, because it causes pollution and health hazards when released into the atmosphere or into the water.

The solution to this issue that we have been working on since the release of the positive thermal CTP system is to reduce the amount of solution waste by using smaller amounts of a concentrated solution for replenishment. At this moment, there are two factors enabling this low-amount high-concentration replenishment: one is a developer solution composition that allows concentration to a very high level, because it does not contain VOC and uses sugar instead of silicate as pH buffer. The other is a precise replenishment management system based on monitoring the conductivity of the developer solution. By combining these two factors we were able to achieve solution waste reduction and printing quality improvement at the same time.

In the case of ECONEX, we took the above ideas even further and succeeded in building a system using the developer replenisher liquid “XP-DR”, which is 30% more concentrated than the previous solution used.

In order to use XP-DR, it was necessary to design plates according to this liquid’s developing characteristics. In the case of positive thermal CTP plate, exposure to light enhances the developability of the photosensitive layer, and then after the processes of penetration of the developer solution and dissolution and dispersion of the photosensitive layer into the developer solution, the development process is completed. In comparison with the existing product (DT-2R), XP-DR has a higher rate of penetration while the rate of dispersion is lower. Due to these characteristics, the image area of the photosensitive layer was more susceptible to damage from the developer solution and also there was a tendency for the non-image area to have residues of photosensitive layer that did not disperse away cleanly. This led us to develop a new plate, XP-F, whose image area has improved developer solution resistance and non-image area has improved developer solution dispersion (Fig. 2).
liquid (DT-2R), and also achieve solubility when exposed that was equivalent to the existing plates (HP-F) (Fig. 3).

On the other hand, at the non-image area, which is the exposed part, we adopted the RDD (rapid dispersion developing) method to facilitate the dissolution and dispersion of the photosensitive layer. With this method, by adding a small amount of resin that has different developability and an excellent dispersion rate to the main resin component, it is possible to enhance the dispersion in the entire photosensitive layer while sustaining the developer solution resistance of the non-exposed part (Fig. 4).

By taking the measures described above, we successfully achieved image development characteristics equivalent to existing systems with the highly concentrated replenisher liquid XP-DR, which makes it possible to reduce the amount of developer waste as much as 40% in comparison with the existing systems, without sacrificing the quality.

2.2 Apparatus for Reducing Developer Waste “XR-2000, XR-5000”

This developer waste reduction apparatus separates the developer waste into distilled recycled water and concentrated waste liquid by vacuum distillation. Except for the finisher which is not suitable for concentration, this apparatus is capable of reducing the volume of all types of waste liquid generated in developing processes and rinsing processes to one eighth, making it possible to construct development systems using alkaline solution with the least liquid waste. Since the distillation is done at around room temperature, the purity of distillation is very high and the pH, BOD, and COD levels of the distilled reclaimed water satisfies the public waste water standards and can be discharged into the water drains. Moreover, the reclaimed water can be used as cleaning water in this apparatus or in a plate processor. This apparatus is employs a heat pump system for power saving and it also contributes to carbon dioxide reduction because of reduced transportation costs of developer and reduced incineration of developer waste (Fig. 5).

Maximum developer waste processing capability of XR-2000 and XR-5000 is 1500 liters per month and 3900 liters per month, respectively, at the operation rate of 100%. This offers a choice of capacity depending on the amount of plates to be processed.
2.3 Thermal CTP Setter “Luxel T-9900G CTP”

Equipped with our original imaging head consisting of LED lasers placed in a line for 623 channels, this CTP platesetter is capable of producing 70 plates per hour of the size 1,030 × 800 mm, which makes it the fastest CTP platesetter for commercial printing use. By adopting lasers with deep focal depth (±50 μm), it is capable of consistently high quality image exposure without print blur. The exposure sequence of this system in which the LED lasers radiate only during the imaging process helps extend the laser lifetime and lower power consumption, achieving 10% to 30% power saving in comparison with our existing products²).

### Table 1 Specifications of thermal CTP setter “Luxel T-9900G CTP”.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output system</td>
<td>External drum scanning</td>
</tr>
<tr>
<td>Compatible plate</td>
<td>FUJIFILM thermal plate</td>
</tr>
<tr>
<td>Plate size</td>
<td>Maximum: 1,160 × 940 mm</td>
</tr>
<tr>
<td>Minimum: 324 × 370 mm</td>
<td></td>
</tr>
<tr>
<td>Exposure size</td>
<td>Maximum: 1,160 × 926 mm</td>
</tr>
<tr>
<td>Light source</td>
<td>Laser diode (623 ch)</td>
</tr>
<tr>
<td>Resolution</td>
<td>1200/1219/1270/2400/2438/2540 dpi</td>
</tr>
<tr>
<td>Productivity</td>
<td>70 plates/hr</td>
</tr>
<tr>
<td>RIP interface</td>
<td>FUJIFILM WORKFLOW XMF/Valiano Flow 3</td>
</tr>
</tbody>
</table>

### References


(In this paper, “ECONEX” is a registered trademark of FUJIFILM Corporation.)

### 3. Conclusion

Our “ECONEX” system that we described in this article is designed for still greater protection of the environment with features such as waste developer use reduction and low power consumption, and is a very effective tool for customers who want more environmentally friendly printing. We are hoping that more customers will choose this system so that we can contribute to the environmental load reduction activities of the entire printing industry.
Two-photon Sensitized Recording Materials for Multi-layer Optical Disk


Abstract

Two types of novel two-photon sensitized recording material writable at 405 nm and 522 nm were developed. The fluorescent dye generation type (F-type) material consists of at least two-photon absorption dye (TPAD) and fluorescent dye precursor (FDP), which is non-fluorescent before two-photon recording and fluorescent after two-photon recording due to fluorescent dye generation. The fluorescence quench type (Q-type) material, on the other hand, consists of at least TPAD, fluorescent dye (FD) and fluorescent quencher precursor (QP), which is fluorescent before two-photon recording and the fluorescence intensity is reduced after two-photon recording at the recorded spot due to fluorescent quencher generation. Both types of material showed quadratic dependency on recording light intensity. A twenty-layer two-photon recording media was fabricated with the fluorescence quench-type material, and two-photon recording and one-photon fluorescent signal readout was successfully conducted.

1. Introduction

Volumetric optical disks for recording, which store data in three dimensions inside the disk, has been attracting attention as the next generation optical data storage media that meet the demands for even greater capacity and for reducing power consumption for the recording of data, and for this, there have been proposals of materials for nonlinear void formation1), heat-mode material with linear absorption2), and two-photon absorption recording material3).

Two-photon absorption recording utilizes the simultaneous absorption of two photons. This is a three dimensional nonlinear optical effect, and it is a way of recording particularly suitable for volumetric recording. The reason is that the recording light can reach deep inside the recording media without attenuation because it is possible to use a long wavelength light that is not linearly absorbed by the recording media material, and further because it is possible in principle to record three dimensionally merely by changing the focal point along the depth direction, since absorption is limited only to the area with strong light intensity, near the focal point.

Data storage media that utilize two-photon absorption must have efficient two-photon absorption which causes desired physical changes in such properties as absorption and fluorescence. A spiropyran derivative4) was the first photochromic material reported to have both of these functions in a single molecule, and since then various photochromic materials have been used for two-photon recording material. Generally speaking, the two-photon absorption cross section of photochromic material is very small and it is extremely difficult to make the two-photon absorption cross section large while preserving the ability of photochromism, and therefore it is not practical to implement two-photon absorption recording using photochromic material. Instead, based on the idea that it is possible first to separate the two required functions and use an independent compound for each of them, making it possible to obtain a highly efficient two-photon recording material by combining a compound which has large two-photon absorption cross section and a compound whose physical properties change in the desired manner, we have been working on the development of separate-function composite two-photon sensitized recording material5).

In this article, we first demonstrate the possibility of achieving the recording density required for practical application (recording capacity per recording layer 25 GB, equivalent to a Blue-ray disk, hereafter BD), and then report the details of an experiment where we successfully conducted two-photon three dimensional recording on a twenty layer medium.
Two-photon Sensitized Recording Materials for Multi-layer Optical Disk

2. Recording/Readout Evaluation System

Prior to performance evaluation of two-photon absorption recording material, we built an evaluation system for two-photon recording and readout. We used FUJIFILM’s newly developed ultra-compact femtosecond pulsed laser F-1A (pulse width 490 fs, pulse frequency 3 GHz, maximum peak power 50 W) for two-photon recording at 522 nm, and a Ti:sapphire laser (Spectra-Physics, pulse width 200 fs, pulse frequency 8 MHz, maximum peak power 200 W) for two-photon recording at 405 nm. In this article, we mainly report on the results of recording/readout experiments using the Fujifilm laser. For reading out the recorded marks formed by two-photon recording we used a 633 nm He-Ne laser or a 405 nm semiconductor laser.

![Fig. 1](image1.png) The optical setup for two-photon absorption recording and one-photon fluorescence readout.

3. Two-photon Absorption Recording Material

3.1 Material Design Principle

In developing highly sensitive two-photon absorption recording material, we chose the idea of two-photon sensitization as the principle. Two-photon sensitization is obtained by combining materials with different functions, namely a two-photon absorption compound and a compound that exhibits the desired physical change (modulating material). This is an excellent material design principle, as the use of a compound with large two-photon absorption cross section provides high sensitivity, while the use of modulating material that exhibits the desired change in physical properties allows necessary flexible adaptation to signal configurations. In this article, we report on a fluorescent dye generation type material in which when an area is two-photon recorded, fluorescent quencher is generated and fluorescence intensity decreases.

3.2 Fluorescent Dye Generation Type Material

Fluorescent dye generation type material consists of two-photon absorption dye (TPAD) and fluorescent dye precursor (FDP). As shown in Fig. 2, this is a non-fluorescent material which has no linear absorption in the wavelength region longer than 400 nm in an unrecorded area. When this recording material is irradiated using a 405 nm or 522 nm pulsed laser as two-photon recording light, two photons are absorbed in the irradiated area causing excitation of TPAD. Excited TPAD induces photoinduced electron-transfer reactions with the FDP also present, and radical cations of FDP are generated, followed by oxidation reactions that generate fluorescent dye (FD) that has an absorption peak around 650 nm. For readout of the recorded signals, first the generated FD is excited using a 633 He-Ne laser whose wavelength is in the absorption range of the FD, and then the induced fluorescence is detected.

![Fig. 2](image2.png) Absorption and fluorescence spectral change of the F-type material upon two-photon recording.

![Fig. 3](image3.png) Two-photon recorded pits (top) and signals from the two-photon recorded pits on the monolayer media (bottom). These signals are recorded via two-photon absorption at 522 nm and read by one-photon excitation at 633 nm.
This recording material provides low-to-high recording where fluorescent signals can be expressed since fluorescent dye is generated in an area where the recording light is irradiated, and this is surrounded by a non-fluorescent background.

### 3.3 Fluorescence Quenching Type Material

Since the diffraction limit of two photons is $1/\sqrt{2}$ times that of one photon, it is expected that by using 522 nm recording light and two photon recording, it should be possible to achieve recording density equivalent to one-photon recording at 373 nm which is close to that of BD, where one-photon recording at 405 nm is used. On the other hand, with the fluorescent dye generating type recording material we discussed in the previous section, the signal readout is a bottleneck for achieving BD quality recording density because the absorption of the fluorescent dye at 633 nm is the signal that is readout. Therefore, we developed a fluorescence quenching type material that allows readout at 405 nm, aiming for higher recording density by enabling signal readout at a shorter wavelength.

The fluorescence quenching type material is composed of three components; two-photon absorption dye (TPAD), fluorescence quencher precursor (QP) and fluorescent dye (FD). For the TPAD and QP, we used the same compounds as the TPAD and FPD, respectively, of the fluorescent dye generating type material. The FD we used is fluorescent dye that originally has a absorption at 405 nm, the readout wavelength, and generates intense fluorescence. This fluorescence is quenched by the quencher (Q) generated by irradiation of recording light (Fig. 4).

![Fig. 4 Absorption and fluorescence spectral change of the Q-type material upon two-photon recording.](image)

Fig. 4 shows the behavior of the signals obtained when the recorded marks created by two-photon recording were read out by irradiating 405 nm continuous wave light from a semiconductor laser on a spin-coated single layer recording film consisting of fluorescence quenching type recording material.

This recording material provides high-to-low recording where darker signals with less fluorescence appear on a bright fluorescent background since the original fluorescence is quenched by the fluorescent quencher generated in the area where the recording light is irradiated.

This result demonstrates that two-photon recording is possible at a recording density equivalent to that of BD, and that one-photon readout signal readout is possible at a short wavelength which is effectively the same level as BD, 405 nm.

### 3.4 Characteristics of Two-photon Recording

Fig. 6 shows the relation between the recording light intensity and the signal intensity (in the case of the fluorescent dye generating material) and the relation between the recording light intensity and the modulation factor (in the case of the fluorescence quenching type material). The wavelength of the two-photon recording is 522 nm for both cases, and the readout wavelength is 633 nm for the fluorescent dye generating material and 405 nm for the fluorescence quenching type material.

The results shown in Fig. 6 clearly demonstrate that the signal intensity and the modulation factor are proportional to the square of the recording light intensity, which confirms that the recording pits were formed by simultaneous two-photon absorption.

![Fig. 6 Relationship between average writing power vs. signal intensity for the F-type material (left) or modulation for the Q-type material (right). The signals were recorded 522 nm of pulsed laser with 50 μs of exposure time. Recorded signals were read at 633 nm for the F-type material and 405 nm for the Q-type material.](image)
3.5 Verification with Twenty Layer Recording Media

For the purpose of confirming the possibility of three dimensional recording using two-photon absorption, we fabricated multilayer media consisting of twenty recording layers using the fluorescence quenching type material and carried out two-photon recording and one-photon readout at each layer. The fabricated media had a structure in which 1 μm recording layers are sandwiched by 10 μm intermediate layers. Fig. 7 shows the result of the multilayer recording experiment. The dark areas surrounding the alphabetical letters are the recorded marks created by two-photon recording. For the sake of the ease of layer identification, we adjusted the recording light irradiation positions so that each layer has a different letter shape left as the non-recorded area.

Fig. 7 clearly shows that we could observe very clear, well separated signals in each of the twenty layers, with effectively no leakage of signals recorded in neighboring recording layers (interlayer cross talk).

4. Conclusion

We developed a two-photon absorption recording material that has a recording density capability in principle equivalent to that of BD, based on the concept of achieving different functions by combining different materials. This material clearly exhibits square dependence on the intensity of recording light, which clearly shows that the recording is due to simultaneous two-photon absorption. In addition, we empirically demonstrated three dimensional recording in a twenty layer recording media consisting of fluorescence quenching type material, showing that it has excellent three dimensional recording characteristics with no cross talk between neighboring recording layers.

We plan to work on further improvement of sensitivity and of recording characteristics in preparation for practical applications.

References

Development of the Server-side Web Browser for Mobile Phone based on the Imaging Technology “GT-Browser”

Kentaro WATANABE*, Takashi MIYAMOTO*, Tetsuya SAWANO*, Arito ASAI*, and Norihisa HANEDA**

Abstract

We have been developing enterprise solutions for mobile phones based on the imaging technology. Compared with an e-mail system, websites in the intranet have not been utilized in the mobile environment because of the poor performance of mobile phones. In this report, we introduce “GT-Browser”, that is a mobile web-browsing system based on the imaging technology for PC-based websites.

1. Introduction

For many years, the Internet Business Development Division in FUJIFILM Corporation has been developing solutions for mobile phones based on the leading imaging technology. Recently, we have been mainly developing solutions for corporations. One of the representative technologies is “GT-Document” that provides a means to convert documents to images and distribute them to a document viewer. This technology has been deployed mainly for making internal documents of a company available for browsing while an employee is outside company premises1).

Meanwhile, an internal business resource which is no less important than documents is the intranet business web system. Typical web systems which employees often want to access outside company premises include attendance records, groupware, sales force automation (SFA) system, and settlement and approval systems. If these systems could be accessed anytime from mobile phones, work efficiency would be increased. However, it is difficult to browse a web system designed for a PC directly from mobile phones due to their limitations. Though installing a mobile website additionally is a common alternative means, the cost of introducing and running such a website is a problem.

To overcome this problem, we developed “GT-Browser” technology which enables the browse of a PC website directly from mobile phones. We applied this technology to the commercial service “Keitai Remote Intra-Access”, which makes it possible to use internal company websites outside company premises through mobile phones (Fig. 1). In this report, we present an overview and describe distinctive features of GT-Browser.

Original paper (Received December 28, 2010)
* Internet Business Development Division
FUJIFILM Corporation
Nishiazabu, Minato-ku, Tokyo 106-8620, Japan

** Internet Business Development Division
FUJIFILM Corporation
Akasaka, Minato-ku, Tokyo 107-0052, Japan
is that GT-Browser is a “thin client” type browser. Since GT-Browser does not receive and store data of websites directly in mobile phones, the risk of information leak from mobile phones is extremely low.

3. System Configuration and Operation Flow

GT-Browser consists of a mobile phone for browsing websites and the GT-Browser server that converts websites to a form to be displayed on mobile phones. Fig. 2 shows an example of the GT-Browser system configuration and operation flow. This configuration is for accessing a web server located in a data center of a customer via the data center operated by FUJIFILM Corporation. The following are detailed explanations of the operation flow in Fig. 2.

(1) Obtain data of a website
To browse a PC website, the GT-Browser server retrieves data of the website such as HTML files, JavaScript files and style sheets according to the request from a mobile phone.

(2) Render the website and extract user interface data
Based on the data of the website, the GT-Browser server renders web pages. Then, the rendered web pages are converted into images suitable for mobile phones. In addition, user interface data of the web pages are extracted for the operation of them from a mobile phone.

(3) Send images and user interface data and display them on mobile phones
The images and interface data of the rendered website are sent to the mobile phone from the GT-Browser server. They are displayed on the mobile phone by a preinstalled application. A screen image of this application is shown in Fig. 3. As can be seen, GT-Browser can display web pages on a mobile phone equivalently as web browsers on PCs.

(4) Apply operations of mobile phones to the GT-Browser server
The user’s operations upon interfaces of the mobile phone are sent to the GT-Browser server, and are applied as actual commands to the website. After the web page is updated in response to the commands, its image and interface data are sent and displayed on the application of the mobile phone again.

4. Technical Features

The following are the main features of the GT-Browser technology:

(1) Operability equivalent to that of PCs
Users of GT-Browser can browse PC websites on a mobile phone using a cursor as they operate a web browser on PCs. Therefore, it is not necessary to develop websites for mobile phones and spend any cost for introducing and running them. In addition, several operation modes besides using a cursor are prepared in GT-Browser.

(2) Smooth zoom and efficient data transaction
Since web pages displayed on mobile phones are preliminarily rendered images, it is possible to expand or shrink them smoothly on mobile phones (Fig. 5). For the reduction of communication traffic and quick display, the size of images is limited to the minimum for displaying on a mobile phone. When users zoom in a website image more than a certain level, an expanded image of the web page is requested to the GT-Browser server to display the image with good quality.
(3) High level of security

GT-Browser is a thin client type browser that displays only images of websites generated by a server on a mobile phone. Therefore, confidential information in the website such as phone numbers and addresses of employees or customers is not sent directly to a mobile phone. In addition, since retrieved images are deleted when the application is closed, there is no risk of information leak from the usage history kept in the mobile phone. Website data in the GT-Browser server for web browsing are managed separately per users, and they are deleted when sessions are terminated. Hence, GT-Browser users can access to websites which contain confidential information securely.

(4) Browse of documents on websites

GT-Browser provides a function to browse documents on websites in conjunction with GT-Document that converts documents to images in a server. This function enables users to read documents attached to websites.

5. Conclusion

In this report, we explained the GT-Browser technology, which provides a means to browse and operate PC websites from mobile phones based on imaging technology. This technology is expected to make internal PC websites of companies more accessible from the outside of company premises and to contribute to enhancing the efficiency of business operations and the security control of confidential information. In the future, we will make every effort to improve the functions and performance of this technology, and explore other applicable markets and products of this technology.

Reference


(In this paper, “JavaScript” is a registered trademark of Sun Microsystems Incorporated. “Keitai Remote” is a registered trademark of FUJIFILM Corporation. Applications for trademark registration of “GT-Browser” and “GT-Document” have been made by FUJIFILM Corporation.)
Application of Hypothesis Verification to Software Development for Photo Products

Tetsuya MATSUMOTO*, Kei YAMAJI*, Kazuma TSUKAGOSHI*, and Toshio MATSUBARA*

Abstract

Generally in the photo market, customers have specific personal memories about their photos to be printed. We took this into account in verifying the usability of our online photobook ordering system. We adopted a well-known hypothesis verification method and improved the verification process by using testers’ own photos in the designing and ordering of a photobook, and printing them in the final product prototype. This approach successfully met the customer needs more accurately.

1. Introduction

Generally speaking, a problem that may sometimes arise during the development of a software product is that too many specifications are given to the software, so that despite the increase in the time and cost required for development, the resulting product does not meet the needs of the users. This problem with specifications is likely due to demands being made for the product that are largely subjective, seeing the product as though it were a person, or that are ad hoc and not well thought out. Specifically, the following are the major issues in the specification requirement phase1):

(1) Narrowing down Requirements

The true needs of the users are not identified. Every function that might be useful is demanded, and there is an excess of specifications.

(2) Obtaining Evidence that Supports the Requirements

The appropriateness of a requirement is not based on valid, objective evidence. The specifications are constantly changed according to the opinions of many people.

What is important in working on these two issues is to collect data based on objective evidence efficiently in a short period of time. It is known that, in order to grasp the needs of the users quickly and to make specifications in an efficient manner, the “hypothesis verification process” is beneficial, where, instead of going through all the possibilities exhaustively, the possibilities are narrowed down using a “guess”, and an issue is identified by verifying the guess2). In general, the hypothesis verification process consists of repeated application of the following three phases: (1) observation and analysis of the situation, (2) making a hypothesis, and (3) verification of the hypothesis3). In the case of software development that uses user interfaces (GUI, hereafter), the verification is done using software prototypes (Fig. 1).

Fig. 1 Hypothesis verification process for GUI software development.

However, in our case, we are targeting software development in consumer photo applications for an online photobook production system, where the usual hypothesis verification process for GUI software development cannot be applied because of the characteristics specific to photographs. Therefore, we improved the hypothesis verification process to be suitable for photography applications, and applied and implemented it to the software development of the photobook production application.

In this report, we describe the characteristics specific to photographs in Section 2, problems with the hypothesis verification process for GUI software development in Section 3, the solutions to these problems in Section 4, and the “hypothesis verification process for photography applications” that we implemented in Section 5. Then, we discuss the result of the application of our process in Section 6, and show the conclusion and outlook in Section 7.
2. Characteristics Specific to Photographs

Photography related products including photobooks give shapes to users’ memories, and have the following characteristics:

(1) Each User has Different Feelings toward Every Single Photo

Each of the users has a different perspective on a photo. Photo related products involve users’ feelings and the value of the product varies depending on the photos used in them.

(2) The Products Contain Photos Taken by the Users

Unlike other generic consumer products such as cameras or bags, the final products contain photos taken by the users. The final products are different for each user.

3. Issues in the Hypothesis Verification Process for GUI Software Development

When the usual hypothesis verification process for GUI software development is applied to the development of photo product applications such as online photobook production, problems like the following arise in the verification phase due to the characteristics we explained in the previous section (Fig. 2):

(1) Valid Evaluation of the Product is Impossible When Data Used Do Not Have Any Personal Attachment

Evaluation of function and operability using test data by users is not valid when the user has no personal feeling toward the data. For instance, evaluation of whether the operation “selecting your favorite photos” fulfills the user’s desires is pointless if the user has no feeling for the data in the first place.

(2) Valid Evaluation with Software Prototypes Only Is Impossible

In the photo application field, the software is not the final product. The users cannot obtain the impressions of the final products from software prototypes and there is no way for them to know what functions and operability are provided with the product, which makes it impossible to give a valid evaluation.

4. Solutions to the Issues

As solutions to these issues, we introduced the following two changes in the verification phase (Fig. 3):

(1) Use of User Data

Data of photos taken by the user are used in the verification so that the user can have a real feeling during the verification.

(2) Use of Product Prototype

Product prototypes of the final product that allow the user to confirm what will be actually obtained are produced. This makes all-around evaluation possible by providing associations between the final product and the impressions of the functions offered.

5. Realization of a Hypothesis Verification Process for Photography Applications

5.1 Overview of the Process

In the hypothesis verification process that we used in this study, we incorporated in the hypothesis verification phase the two solutions described in the previous section, and at the same time, for the purpose of quick specification narrowing, we also introduced a step for clearly determining the target in the situation observation and analysis phase (application of the persona method), and a step for road map drawing in the hypothesis creation phase, which resulted in dividing the three phases into five steps (Table 1).

Table 1 Initiated process.

<table>
<thead>
<tr>
<th>Usual process</th>
<th>Our process</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Situation observation and analysis</td>
<td>Step 1: Situation observation and analysis (target user identification)</td>
</tr>
<tr>
<td>(2) Making hypotheses</td>
<td>Step 2: Making hypotheses</td>
</tr>
<tr>
<td>(3) Verification of hypotheses</td>
<td>Step 3: Concretization of hypotheses (prototype development)</td>
</tr>
<tr>
<td></td>
<td>Step 4: User verification</td>
</tr>
<tr>
<td></td>
<td>Step 5: Reexamining the specifications</td>
</tr>
</tbody>
</table>
5.2 Process Details

5.2.1 Step 1: Situation Observation and Analysis (Target User Identification)

It is clearly determined what is to be provided to whom. The profiles of the target users are identified so that their images can be shared. Specifically, we used data of the target users, ranging from their basic information (age, gender, occupation, etc.), to more detailed information (family structure, hobbies, life styles, etc.), their photograph-related activities (the number of photos taken by the user per month, storage method, etc.) and so on, to obtain clear images of them to be shared.

The key is to have a clear picture of the target users.

5.2.2 Step 2: Making the Hypotheses

The problems are identified and the hypotheses for solving them are set. Specifically, issues to be resolved in designing a photobook (such as selection of photos out of huge collections of photos, time consuming work required for finding a satisfactory layout) are identified, and hypotheses for making the photobook designing process easier are made.

Since verifying all the hypotheses requires a huge amount of time and effort, it is important to rank them for priority, plan the steps of a lengthy solution strategy, and create a roadmap of items to develop and verify.

5.2.3 Step 3: Concretization of the Hypotheses (Prototype Development)

The concrete steps of the solution strategy were made clear, and the items to be verified were narrowed down. Specifically, we developed software prototypes for the purpose of confirming the function and operability, and product prototypes for the purpose of associating the product with images of satisfaction it brings and the functions provided.

In software prototyping, it is vital that the items to be verified are narrowed down, for the sake of obtaining the verification result quickly, and that product prototypes are made that allow confirmation of the effect of the provided function.

5.2.4 Step 4: User Verification

The solution strategy that is created based on the hypotheses was verified. Specifically, we observed the users operating a software prototype containing their own data, while looking at a product prototype.

It is vital to use the data of the users. Otherwise, the users are not able to have real feelings when they use the prototype and the user’s impressions are insignificant.

5.2.5 Step 5: Re-examining the Specifications

Based on the results of verification, the specifications were reexamined. After the verification by the users was completed, the developers simulated the behaviors of the users to confirm the validity of the verification results. When the results were not satisfactory, the hypotheses were changed and used in the next verification (one such example is the method for displaying failed photos during the photo selection).

The more time passes after the verification, the more the mindset of the developers dominates over that of users. Therefore, it is important to reexamine the specification while the verification results are fresh and new.

6. Result of Applying the Hypothesis Verification Process

The result of applying the process described so far to the software development of a photobook production system is as follows.

6.1 Effects of Use of User Ddata

By using the actual data of the users, it was possible for the users to have serious interest in the system, which helped us determine the desirable method of use and functions and also discover some potential needs of the users, benefits for which we did not make hypotheses (an example of this is the way to display failed photos). Moreover, we could obtain supporting evidence for the hypotheses, which contributed to making suitable corrections of the hypotheses based on the verification results (Table 2).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Number of hypothesis at each cycle.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First cycle</td>
</tr>
<tr>
<td>Total number of hypotheses</td>
<td>5</td>
</tr>
<tr>
<td>Verified hypotheses</td>
<td>1</td>
</tr>
<tr>
<td>Corrected hypotheses</td>
<td>3</td>
</tr>
<tr>
<td>Discarded hypotheses</td>
<td>1</td>
</tr>
</tbody>
</table>
There were four hypotheses (some were discarded) in the verification of UI and device operation features in the first cycle and four hypotheses (some were discarded) in the verification of function in the second cycle that differed greatly from the actually obtained evidence, but in the third cycle all of the hypotheses were verified.

![Diagram showing accuracy of hypothesis at testing cycle.](image)

### 6.2 Effects of Product Prototyping

By presenting to the users both the function and the finished product at the same time using the software prototype and the product prototype, the users could understand how a function of the software would be reflected in the actual product, which helped them make valid evaluations. For example, in the case of the function for displaying all the dates that the photos were taken, the users were not particularly impressed with it in the software prototyping verification but when they saw it in the product prototype, almost all the users said that they wanted the function. This is a hypothesis that would have been mistakenly verified with software prototyping only. Moreover, by obtaining the impressions of the final product using the product prototype, it was possible to confirm the needs of the users regarding the use and cost of the product.

### 6.3 Evaluation Result in the Market

The functions that were evaluated highly in the verification (such as the automatic layout function) were introduced in our online ordering web sites, and the satisfaction with this function was surveyed before and after the introduction. The proportion of the users satisfied with the results of automatic photo layout was increased by 24 points, indicating that the introduction of the function was beneficial.

### 7. Conclusion and Outlook

In this report, we established a new process for applying the general hypothesis verification process for GUI software development to software development of a consumer photo application, an online photobook production system, and by applying this new process to the actual development project, we successfully obtained better understanding of the needs of the users. In the future, we aim to refine this process by applying it to more real projects, and so to contribute to the development of functions which have true value to users.

### References
Introduction and Practice of Statistical Project Management Technique in Software Development

Masashi AISÔ**, Kouki YUASA**, and Keiichi SUZUKI*

Abstract

We implemented innovative project management in order to strengthen software development technology. We acquired project management skills based on CMMI (Capability Maturity Model Integration) which is used as a model for QCD (Quality, Cost and Delivery) improvement all over the world, and practiced statistical project management (e.g., establishing process performance baselines and models, controlling reviewing speed to thoroughly discover software defects and so on). As the result, we improved QCD, reducing the number of times to correct defects by increasing the defect discovery rate in the early phases of development.

1. Introduction

Software has become an indispensable technology field for the FUJIFILM to provide highly functional, high-performing products in various areas including medicine. The importance of software development is increasing even more because of the advancement of the technology used in products and the increase in the complexity of systems. This has made higher-than-ever competence in skills, know-how and quality management necessary for managing software development.

With the situation being like this, FUJIFILM Corporation and the FUJIFILM Software Co., Ltd. together introduced and carried out project management for the enhancement of software development capability.

We acquired project management skills based on the Capability Maturity Model Integration (CMMI) model, which is widely used all over the world as a project management technique for the purpose of improving quality and lowering cost and delivery time (QCD), established performance baselines and performance models, and then implemented our own statistical project management system with features such as controlling the speed of reviewing for defect detection.

As a result, we could reduce the number of defect corrections needed in the last phase of the project by improving the defect detection rate at earlier phases, and achieve improvement in QCD due to the reduction in the delay in delivery and in the man-hours required for defect corrections.

We report on the project management technique that we practiced and the benefit obtained.

2. Limit of the Existing Project Management Techniques

The project management technique that has been used in the Fujifilm provides guarantees for product quality by first defining the standard development process of an organization, and then running the project on the basis of this standard process. In this way, the development process and the finished product are managed.

Moreover, we have established a system where the development data of all projects are stored in a database shared by the whole organization, so that the experience of the past can be used as references for planning and cost estimation.

However, in order to make sure that QCD is improved and to make contributions to the organization, it is necessary to quantify the QCD objective for a project and to be able, over the whole duration of the project, to control the project statistically and to predict whether or not the objective is reachable or not. Since the existing project management process does not include a framework for managing projects in such a way, there are limits to the management that can be carried out with the existing system. The process based on statistical data that we explain in the next section is indispensable for advanced project management.

3. Details of the Process Based on Statistical Data

For a process based on statistical data, it is required that the following two process areas are covered: “Organizational Process Performance”, in which action is chiefly taken as a
group to make progress in project management and process improvement, and “Quantitative Process Management”, chiefly comprising activities of the development project1).

3.1 Organizational Process Performance

The purpose of defining organizational process performance is to understand quantitatively the performance of current processes in order to meet the QCD objective. Specifically, the following activities are required:

(1) Process Performance Data
The performance data of the project is analyzed, and then the data for each process are analyzed and compiled.

(2) Process Performance Baseline
This is a statistical index that indicates the process capability. Used as a benchmark for comparing the actual and expected process performance.

(3) Process Performance Model
A statistical model is created from the process performance data and used for predicting the future results of the process.

3.2 Quantitative Project Management

The purpose of the quantitative project management is to achieve the QCD objective set by the project by managing the major processes in the development project using a statistical method. Specifically, the following activities are required:

(1) Setting the Quantitative Objective of the Project
A quantitative objective regarding the QCD of the project is set.

(2) Selection of the Processes to be Statistically Managed
Processes that are important for achieving the objective are selected and statistical management methods are used for them.

(3) Abnormality Detection and Correction
The focused processes are managed statistically and any abnormality in the data that may hinder achievement of the objective should be detected and corrected.

(4) Prediction on Objective Achievement
The state of the project is analyzed statistically and predictions on the possibility of achieving the objective are made. The process performance baseline and the process performance model that were established during the organizational process performance evaluation activities are used for the activities listed above.

4. Application to a Project

We applied the process based on statistical data to the medical console development organization.

4.1 Story-making for Introducing the Project Management Technique Based on Statistical Data

In order to introduce a process based on statistical data, we set up a story of project management for achieving the organizational target. Then, we analyzed the data of the medical console development organization in the past and identified what needs to be improved, and considered the entire story up to predicting the results of the changes.

4.1.1 Analysis of the Number of Man-hours Required for Defect Corrections

Although in any development project, delivery of high quality products as scheduled is set as a target, the reality is that not all projects are always successful in delivering on schedule.

As a result of the analysis of data on the medical console development organizations in the past that we conducted to identify the cause of failing to meet the deadline, we found out that the number of man-hours required for defect corrections is highest in the very last system testing phase, and is the biggest factor in delaying the delivery.

As seen in Fig. 1, the result of the analysis shows that the man-hours required for one defect correction is about twenty times more in the last system testing phase than in an early system design phase.

This led us to think that, by finding out defects in an early system design phase and the coding phase, we can reduce the number of defects that occur in the last system testing phase, which will lead to the decrease in the overall man-hours required and help prevent delay in delivery.

![Man-hours required for correcting one defect](image)

Fig. 1 Relative time necessary to correct one defect in each phase.

4.1.2 Analysis of Reviewing Speed and Defect Density

For the purpose of working out measures for finding defects in the earlier phases such as designing and coding and reducing defects occurring in the last system testing phase, we analyzed the correlation between the defect density (the number of defects found relative to the size of the delivered software) and the reviewing speed (the size of software reviewed per hour) in the data obtained from the past medical console development organizations.
As shown in Fig. 2, we thus found out that in both the designing phase and the coding phase, the effect of reviewing speed on defect density changes at a certain reviewing speed.

Based on this we introduced a policy that, during the reviewing in the design phase and the coding phase, the reviewing speed should be controlled appropriately so that the reviewer is able to find out as many defects as possible. This is considered to reduce the number of defects found in the later phases and so contribute to the reduction of man-hours required for defect corrections in total.

![Correlation between the reviewing speed and the defect density](image)

Fig. 2 The correlation between reviewing speed and defect density.

### 4.1.3 Predicting the Effect to be Achieved

Based on the data obtained in the past on the defect density in each phase and the number of man-hours required for defect corrections, we calculated the effect of maintaining appropriate reviewing speed to find defects in the early designing phases and coding phase. It was thus estimated that the number of man-hours required for defect correction will be reduced by 56.6%.

### 4.2 Executing the Organizational Process

#### Performance Management

##### 4.2.1 Establishing Performance Baseline

In order to find defects in the early designing phases and coding phase by controlling the reviewing speed, it is necessary to manage the defect density and the reviewing speed in each of the development phases.

Based on the data of medical console development organizations in the past, we used statistical techniques to establish performance baselines regarding the defect density, the reviewing speed and the number of man-hours required in defect correction, which enabled the comparison of the actual process performance and the expected process performance.

In establishing and applying the performance baselines we considered the following points:

1. A baseline should consist of an average value and the standard deviation. This means that the actual performance of an organization is to be within a range distribution.

2. The baselines are created for the purpose of continuous monitoring; and are updated in half-term cycles. Any such changes in baselines are monitored.

#### 4.2.2 Establishing Performance Models

With the purpose of managing the product quality at each phase of the development, we established performance models for defect density and the number of man-hours used for defect correction, which made it possible to predict the defect density and the number of man-hours at the system testing phase, which is the very last phase of development.

The defect density prediction model is built by applying regression analysis on the data obtained from the medical console development organizations in the past. By substituting the values of accumulated defect density for each phase of a project under development in a regression formula, the predicted defect density in later phases can be obtained.

In the case of the prediction model for the number of man-hours used in defect correction, by using the data on the accumulated man-hours used in defect correction and the defect density in each phase of a project under development, it is possible to obtain a prediction of the man-hours required for defect correction in later phases.

### 4.3 Practicing Quantitative Project Management

#### 4.3.1 Setting the Objective of the Project

In order to execute quantitative project management, it is necessary to select the processes to be quantitatively measured, and to set the product quality and performance objectives of the project, based on the organizational goal, the performance baselines, and the performance models.

An objective that the quantitative project management aims to achieve should satisfy the following two properties:

1. It should be expressed in terms of a number (or numbers), with a range of a certain width
2. It should be manageable with a statistical method during the course of the project.

Moreover, in order to make the quantitative project management actually possible, it is necessary to come up with a system by which the projects can be managed well even in the middle of a phase, for example, by setting intermediate objectives for each phase. Having considered all these aspects, the numerical objectives are set for each project.

#### 4.3.2 Early Abnormality Detection and Correction

##### Using a Management Chart

Based on the organizational baselines and the project objectives, we prepared a management chart which shows the defect density and the reviewing speed in each of the development phases and made efforts to find abnormalities and correct them at an early stage. 2)
Fig. 3 shows an example of an X-R management chart. In the designing phases and the coding phase, one reviewing report is plotted as a point, while in the testing phase, the number of tests conducted per day and the number of defects found per day are recorded and the hourly and daily values of the defect density are calculated. This is plotted in the chart as one point.

By checking using the chart above, the judgment whether the process is deviating from its normal progress was made. The rules for making this judgment were defined by each organization, and when one of the conditions given below is satisfied, we considered that it is likely that the deviation may have happened. The possibility of any of the conditions given below happening should be very low, so when it is the case, it is possible that it was a phenomenon caused by some unusual factor:

1. Eight consecutive points appear on the same side
2. Five consecutive points appear on the same side, and four of those five are outside the 1σ line
3. Three consecutive points appear on the same side, and two of those three are outside the 2σ line
4. Any point appears outside the 3σ line

Fig. 4 shows an example of the case that there is a point beyond the 3σ line. In a case like this, we analyzed the cause of deviation and took some corrective measures, for the purpose of keeping it from happening again.

4.3.3 Prediction of the Defect Density and the Number of Man-hours Required for Defect Correction Based on the Prediction Model

The defect density prediction model and the prediction model for the number of man-hours used in defect correction established by the organization were applied to a project to predict the defect density and the number of man-hours required for defect correction at the point when the system testing phase is finished.

In each of the development phases of a project, the data for the defect density and the number of man-hours used in defect correction were substituted in a regression formula, and it was possible to estimate those values for the later phases. Such estimates were used in determining whether the product quality target may be achieved or not in each phase.

5. Results Achieved

5.1 Improvement of the QCD

5.1.1 Reduction of the Number of Defects in the Testing Phase (Q)

In the design phases and the coding phase, the reviewing speed was controlled appropriately so that it was possible to find many defects in these earlier phases. Consequently, the number of defects found in the later system testing phase was reduced. In comparison with the project average before this management technique was introduced, the defect density during the system testing was reduced by 41%.

Moreover, by exploiting the prediction models and by strengthening monitoring capability using management charts, we could detect abnormalities earlier and take measures to avoid recurrence of similar defects.

5.1.2 Reduction of the Number of Man-hours Required for Defect Correction (C)

The reduction of the number of defects in the testing phase described in the previous section contributed also to the reduction of the number of man-hours required for defect correction. In comparison with the project average before this management technique was introduced, the man-hours spent on defect correction was reduced by 52% during the system testing, and by 32% in all development phases.
5.1.3 **Reduction in the Delay in Delivery (D)**

Due to the reduction of the man-hours required for defect correction in the system testing phase, which was the biggest factor in the delays in delivery, we could improve the degree of lateness of delivery of the project to be ±1.0%, close to delivery on time in each case, after introducing this new management technique, whereas the figure was ±18.6% before this technique was introduced.

5.2 **Obtaining a CMMI Maturity Level 4 Rating**

A formal appraisal of the medical console development organization of the FUJIFILM Corporation and the FUJIFILM Software Co., Ltd. was conducted in March 2010 by a CMMI lead appraiser certified by the Software Engineering Institute at Carnegie Mellon University. We were appraised to have a maturity level of 4. In Japan, only two companies have been appraised to have a maturity level rating of 4 or more, under the current CMMI-Ver. 1.2, and we are the third such company.

6. **Conclusion**

In this report, FUJIFILM Corporation and FUJIFILM Software Co., Ltd. jointly worked on the introduction of a statistical project management scheme. For that purpose, we acquired project management skills and established performance baselines and performance models. Then, we implemented our own statistical project management, with features such as controlling the reviewing speed for efficient defect detection. As a result,

- We identified issues that need to be improved after analysis of past data, and predicted quantitatively the improvement achieved by proposed measures.
- In order to realize quantitative project management, which is the basis of statistical project management, we set numerical objectives and established our own performance baselines and performance models to be used for projects.
- The improvement achieved was demonstrated quantitatively.

The results achieved by the introduction of this statistical project management technique were in the direction that the medical console development organization was striving. However, it is necessary to continue to work on improvement to enhance our software development competence further. We plan to improve our project management technique in software development and extend this technique to products and services other than medical consoles.

---

**References**


(In this paper, “CMMI” is a registered trademark in U.S.A. of Carnegie Mellon University, U.S.A., and it refers to a scheme for assessing the process maturity of development organizations in terms of five maturity levels, developed by the Software Engineering Institute of Carnegie Mellon University.)
Next Generation of Digital Motion Picture Making Procedure: The Technological Contribution for Standardization of AMPAS-IIF

Yasuharu IWAKI* and Mitsuhiro UCHIDA*

Abstract

A new procedural workflow for the making of digital motion pictures is under development by the industry organization “AMPAS (the Academy of Motion Picture Arts and Sciences)”. The workflow targets the facilitation of digital cinema production comprising a wide range of procedures. FUJIFILM contributed in the solution of one of the major technical issues: reference rendering transform. This transform needs to have “Film-look” reproduction, huge dynamic range coverage and very precise accuracy for its inversion. Completion of this transform enabled feasibility testing of this workflow. At this point, the workflow has a satisfactory quality and is effective enough to be implemented.

1. Background and Objectives of AMPAS-IIF

The development of digital imaging technology allows more and more feature films to be made using the DI (Digital Intermediate) process, which means - whichever the input is (film or digital), whichever the output is (film or digital), any intermediate process including editing, visual effects, and color correction - all processes were carried out utilizing digital files. There were de-facto standard file format DPX and de-facto encoding procedures Cineon for DI, but Cineon is a very vague specification with no assurance of the same color for the same code value. As a result, every facility started to use different code values in various workflows, leading to tremendous inefficiency and quality loss in the process.

In response to this situation, AMPAS (the Academy of Motion Picture Arts and Sciences), started to discuss new standards for digital motion picture workflows in 2004. The goal was to create a new standard for the digital motion picture making procedures, which would include the clear definition of color spaces and specific procedure of image rendering. This new process was named the Image Interchange Framework (IIF).

The AMPAS committee announced that more than 30 companies would contribute to the development process. FUJIFILM joined this project in 2005 and contributed in the development of new standards in many sub-projects. In this article, we will provide a basic understanding of AMPAS-IIF and the significant technologies FUJIFILM contributed.

2. Basic Understanding of AMPAS-IIF

AMPAS-IIF is intended to achieve its various applications in diverse use cases. It consists of several encoding color spaces and transformations between these color spaces which are clearly defined for easy understanding of the pixel value meaning (Fig. 1).

![AMPAS-IIF architecture](image)

**Fig. 1** AMPAS-IIF architecture.

2.1 Encoding Color Spaces

2.1.1 ACES

ACES stands for “Academy Color Encoding Specification”. It is a scene-referred color space and RGB primary (see Fig. 2) was selected to cover all of the spectrum locus. This means all of visible colors can be expressed in positive RGB values. ACES images are encoded in 16-bit float. This means it can express an unlimited range of colors, and can be saved in the OpenEXR file format which is the de-facto standard for saving floating point images.

![Color spaces](image)

**Fig. 2** Color spaces.
ACES is the principal color space of AMPAS-IIF. ACES images are used for archiving. Camera film images are converted to ACES. Digital camera data are also converted to ACES. CGI (Computer Generated Imagery) is also rendered to ACES. ACES is a connecting color space and all of the editing should be done in ACES. Color correction will be done to ACES images.

ACES is defined as scene-referred color space, but it is not necessary to express very precise scene colors. Above all, ACES white point is set to D60 (CIE standard illuminant), and it would never match that of the actual scene. It can also include an input device characteristic as well as artistically controlled color reproduction.

Another important point is that the same ACES values must be rendered to the same color, making it possible to observe the same color in different output devices. This will be explained later.

2.1.2 APD/ADX

APD stands for “Academy Printing Density”. ADX (Academy Density Exchange Encoding) is the code values of APD, and their relationship is defined with one to one mathematical calculations.

APD is defined very clearly by its spectrum sensitivity (see the top left of Fig. 3). Given the spectrum transmittance of the OCN (Original Camera Negative), all facilities can get the same APD values. The spectrum density was determined to match the product of the spectrum sensitivity of print film and printer’s light. Fortunately, the spectrum sensitivity of Eastman Kodak’s positive film and FUJIFILM’s were very similar. By using the most popular printer’s light, we could decide the definition to a single set of spectrum sensitivities for APD.

2.1.3 OCES

OCES stands for “Output Color Encoding Specification”. This is the definition for the internal use in the IIF. No end-user ever handles OCES images directly. OCES is the output image color space targeted for the reference display device which would have a more than 1,000,000 to 1 dynamic range. OCES images can be acquired by rendering RRT (which will be explained later) to ACES images. Therefore, the same ACES images would be converted to the same OCES images every time.

2.2 Input Transform

2.2.1 Digital Camera to ACES: IDT (Input Device Transform)

The digital camera image would be transformed by IDT to ACES images. Usually, digital cameras have a function to encode colors according to its own data format. AMPAS-IIF requires image data which must be converted to scene-referred ACES images, so IDT’s role is to make an inverse transformation from the encoded image data through raw image data to ACES image data. The most important part of this transformation is a 3×3 matrix to convert digital camera spectrum sensitivity color space to ACES color space defined by ACES primaries.

2.2.2 APD/ADX to ACES and vice versa: Universal Unbuild and Universal Build

The role of OCN is simply to convert original scene colors (ACES) into OCN density (APD). We call this transformation a “Build” function. The inverse transformation from APD to ACES is called an “Unbuild”.

Every OCN has its characteristic to achieve its own image reproduction. AMPAS has defined “Universal” transforms for both directions, “Universal” means that there is only one transform. As a result, a different OCN image results in a different ACES image even if the same scene was captured. In other words, “Universal Unbuild” was chosen for the typical OCN characteristic, and there remain different OCN characteristics in ACES image.

2.3 Output Transform

2.3.1 RRT (Reference Rendering Transform)

RRT is the only one transform from ACES to OCES. We will explain what was required for this and how we developed the ultimate RRT in a later section.

2.3.2 ODT (Output Device Transform)

ODT is the transform to convert OCES into an actual output device format which has a specific and limited dynamic range and limited color gamut. Usually, ODT is expressed by a simple 1D LUT (Look up Table) and one 3×3 matrix. The simplicity of the ODT is brought about by the definition of the OCES transformed by complex RRT. We can easily calculate proper ODT for many different output devices.

2.4 Use Cases

In this section, we will show the typical procedure based on AMPAS-IIF.

2.4.1 Film Capturing and Digital Projection

1) OCN is scanned into ADX through a film scanner.
2) ADX is transformed to ACES.
3) Editing and grading are accomplished using ACES images.
4) ACES images are rendered by RRT/ODT to a digital projector.

2.4.2 Digital Capturing Film Out

1) Digital camera raw images are transformed to ACES by its IDT.
2) Editing and grading is accomplished using ACES images.
3) ACES images are rendered by RRT/ODT and transformed by inverse print film functions to get ADX code values for film recording.
4) The internegative is recorded and printed on print film.
3. Requirements and Difficulties of RRT/ODT Design

There was a strong demand for Reference Rendering Transform (RRT) inheriting the characteristics of scene reproduction of the film. The major elements of AMPAS-IIF is RRT that converts scene-referred colorimetry image data (ACES) to output referred colorimetry image data (OCES), providing a “film-like” image in the theater viewing environment.

In the traditional film-based production, which has evolved for several decades through collaborative efforts between film manufacturers and cinematographers, an original scene was shot using color negative film, printed onto print film and projected on the screen. This film system has achieved an excellent scene reproduction cultivated over decades.

In order to satisfy the demand mentioned above, the AMPAS-IIF concept requires RRT to meet the following:

- RRT tone scale has lumiance dynamic range more than 6.0 logE or 1,000,000 : 1.
- RRT maps all ACES data to OCES data.
- The tone reproduction and color rendering of the RRT when used with an ODT are similar to those of the film system.
- The ODT handles primarily lumiance dynamic range mismatches between OCES and viewing device.
- The RRT is invertible to a reasonable level of precision.

ACES has no limitation of dynamic range and color gamut. OCES has a wide dynamic range. To design the “film-like” transform from ACES to OCES was very challenging. The difficulties in RRT/ODT design are as follows:

- The transform must cover a huge color space which has never been attempted before.
- The transform must have a high quality and reasonable architecture appropriate to be a future standard.
- There is no common understanding of the “film-like” reproduction design. RRT should reproduce scenes equivalent or greater level than film.

Many attempts have been made to develop RRT by many people, such as to describe output colors by using a viewing model of color science, or manipulation to expand the print film preview 3DLUT. All of them failed to satisfy all requirements at the same time.

4. RRT/ODT Design

4.1 Outline of the Design

After we started to seek for the solution, we also encountered a lot of difficulties. But we came up with a new idea of RRT/ODT design. It was to expand the mathematical model of a print film simulation.

First, we developed the very precise print film reproduction simulation in a mathematical model. We expanded its dynamic range by extending the tone curve and expanded the color gamut by the saturation control method.

4.2 Print Film Simulation (PFS)

Print film simulation in a mathematical model is the starting point of RRT development. FUJIFILM already had developed a color reproduction simulation method for the color paper. We applied this technology to motion picture print film and achieved ultimate accuracy.

The PFS consists of the following steps.

1) Calculation of printing density of color negatives by integrating the negative stock transmittance spectrum with the print film’s spectral sensitivity.
2) Acquisition of Analytical Dye Amount (ADA) by converting printing density by using the print film’s exposure versus dye amount curve (ADA curve). ADA curve is obtained by color ramp exposure and channel independent density calculation.
3) Addition of CMY dye spectrum corresponding to each ADA value to print film base transmittance, bringing an estimated print film transmittance spectrum.

The calculation flow of the PFS is shown in Fig. 3, and the accuracy of the simulation is shown in Fig. 4. The difference between this calculation and actual film color is less than 2.0 in average delta E.

![Diagram for PFS](image)

Fig. 3 Diagram for PFS.

![Comparison between PFS and actual print film](image)

Fig. 4 Comparison between PFS and actual print film.

*FUJIFILM RESEARCH & DEVELOPMENT (No.56-2011)*

39
Since this method is based on parameters like ADA tone curve, dye spectrum and base spectrum, it could be a good model for the expansion of the dynamic range and color gamut.

4.3 Dynamic Range Expansion

Since the print film’s dynamic range is about 3.0 or 1,000 : 1, we needed to expand it to more than 6.0. We tried to extend the tone curve straightforward toward negative dye amount (Fig. 5 (a)). However, the large negative value of ADA caused extremely highly-saturated colors and unbalanced high saturation in different colors of hue, therefore a big hue shift was observed in saturation-increased colors (Fig. 5 (b)).

After several trials with ADA tone curves, we found that the expansion of ADA tone curve in subtractive color space brought about a tremendous drawback. What we finally concluded was that the expansion in the ADA tone curve should be limited to a minimum, and that the main expansion would be applied in additive color space. It means that once we obtain XYZ values from calculated transmittance spectrum and RGB values expressed in ACES primary definition form linear combination of XYZ, we only need to apply the tone curve expansion in order to achieve a high dynamic range in additive color space containing those values in principle. This expansion method worked very well. The results are shown in Fig. 6, and this method had basically none of the drawbacks that the previous method had.

4.4 Color Gamut Expansion

Following to the expansion of dynamic range (4.3), there are requirements for better color reproduction in bright colors. For ODT, when the dynamic range is compressed from 6.0 to about 3.0 that of a real output device, colors close to highlight suffer not only tone scale compression but also saturation reduction. It seems to indicate that RRT and ODT rendering is not an improvement from print film reproduction.

We attempted to expand the bright color gamut by developing “saturation-preserving tone compression” and applying it in the RRT. This is a combination of the RGB LUTs and YCC (or L*a*b*) LUTs. The first step expansion of the tone curve is applied in ACES primary by RGB LUTs. The next step is the half compression of gamma also in ACES primary. The final compression was processed after converting to YCC and only Y channel undergoes gamma compression to targeted dynamic range of 6.0. This final process preserves the saturation of colors in this region. As a result, compared to the previous method of which compression is done in the entire RGB color space, bright color saturation is increased and coverage of color gamut is expanded. Fig. 7 (b) shows the color gamut of this method.

![Fig. 5](image1.png) First trial of dynamic range expansion.

![Fig. 6](image2.png) Final version of dynamic range expansion.

![Fig. 7](image3.png) Gamut expansion with 1D LUT.
4.5 Design for the Ideal Gray Tone

The final problem in the RRT and ODT design is the gray tone scale issues.

Print film has a yellowish tinted highlight for better reproduction of skin tones. In other words, it sacrifices neutral grays for better skin tone reproduction. However, for an ideal color reproduction system, the gray tone scale should be neutral from the beginning to end for easy understanding and customization.

There was a controversy insisting that gray tone scale may work better for AMPAS-IIF standard. We made a couple of system gray tone scale examples and made evaluation of them.

Finally, we found that both proper skin tone color reproduction and neutral gray tone scale could be achieved by optimizing saturation control (4.4). AMPAS members agreed with our proposal, and the system gray tone scale was set to neutral and white point set to D60. It contributed to simple system design, easy implementation and customization of AMPAS-IIF.

4.6 Inverse Calculation Accuracy

The last requirement we had to meet was to achieve invertibility. Fig. 8 (a) is the RRT calculation diagram. Our RRT calculation includes conversion from multi spectral data (eg. 81ch) into 3ch (RGB) data by integral calculation. Analytically, this conversion is difficult to calculate the inverse conversion. Therefore we transformed the inverse function to the combination of 1D LUTs and 3D LUT. However, simple application of non-linear 3D LUT by linear interpolation results in unacceptable errors in inversion. 3D LUT is very non-linear and applying this 3D LUT by linear interpolation results in unacceptable errors.

To reduce the errors, we introduced a shaper matrix for the 3D LUT. The shaper matrix is designed to make the shape of RRT’s 3D LUTs close to ideal cubic. The shapes of 3D LUTs are shown in Fig. 8 (b). By this method, we achieved the roundtrip error 0.14 in average deltaE. Its accuracy was more than required and the difference between before and after roundtrip images was unrecognizable.

5. Conclusion

FUJIFILM’s dynamic range expanded print film simulation technology enables film-like reproduction from digital camera and CGI through wide scene color space. Furthermore, FUJIFILM’s color gamut expansion technology enables maximum use of the color gamut of the digital projector. Contributions of RRT and ODT enabled us to use AMPAS-IIF in real projects. Currently, a lot of projects are testing the use of RRT and ODT, and all of the projects are achieving positive results.

Several issues remain in AMPAS-IIF. FUJIFILM continues to contribute to the AMPAS-IIF standardization and to the development of the motion picture industry.

References

1) Academy of Motion Picture Arts and Sciences (AMPAS) Specification S-2008-001: Academy Color Encoding Specification (ACES).
2) Academy of Motion Picture Arts and Sciences (AMPAS) Specification S-2008-002: Academy Density Exchange Encoding (ADX) and the Spectral Responsivity Defining Academy Printing Density (APD).
Visualization of Our Environmentally Conscious Activity by Implementation of Carbon Footprint Index to FUJIFILM Pre-Sensitized Plates

Katsuyoshi ASAKURA*, Naoki YOSHIKAWA**, and Yoshiko OONUKI***

Abstract

FUJIFILM has established a closed loop recycling system for aluminum-based pre-sensitized plates (PS plates) used in lithographic printing, which will significantly encourage our customers to reduce environmental impact of the graphic industry. FUJIFILM will communicate our pro-environmental efforts by way of the Carbon Footprint Label. Life cycle GHG (Greenhouse Gas) emissions of the PS plate were calculated as “Carbon Footprint of Product (CFP).” The closed loop recycling system showed remarkable GHG emission reduction compared with the open recycling system showing only modest reduction. The CFP is a valid communication tool to demonstrate GHG reduction explicitly. The CFP will encourage customers to recycle PS plates in the closed loop system.

1. Life Cycle Assessment and Carbon Footprint of Products

A life cycle assessment (hereafter “LCA”) is a technique to assess the environmental impact of a product, which involves quantifying the impact caused in every stage of the product life, i.e., from raw material extraction through disposal or recycling (“cradle-to-grave”) and calculating the accumulated impact (see Fig. 1).

The procedures of LCA are set forth in a series of ISO standards:

ISO14041: LCA principles and framework
ISO14044: LCA requirements and guidelines

On the other hand, the carbon footprint of products (CFP, hereafter) is an index for a specific environmental impact, i.e., the greenhouse effect, and it quantifies the total greenhouse gas (GHG) emissions of the entire life cycle of a product1).

These days, CFP has been attracting a lot of attention internationally, and various CFP system pilot projects are being carried out not only in Japan but also in the U.K. and in several other countries. An international standard is currently under development by ISO, and is scheduled to be issued in 2012.

ISO14067: CFP quantification / communication

In Japan, three year pilot CFP projects have been going on since 2009, under the direction of the Ministry of Economy, Trade and Industry2). The main activities of the system include standardization of a GHG emission calculation method for each product, carried out chiefly by that industry (the manufacturers and the trade associations). Then, the manufacturers have the actual data they collect according to that calculation method verified, and if approved, their products are labeled accordingly. The first pilot projects are largely for foods and daily-use commodities, but the scope projects will gradually expand to industrial products.

Fig. 1 Conceptual diagram of LCA.
2. **Background of Our Involvement in Identifying CFP of PS Plates**

2.1 **GHG Emission by the Fujifilm Group**

Among the GHG emissions in the entire life cycle of products by the Fujifilm Group, the aluminum we purchase as raw material (manufacturing), almost all of which is used for substrates of PS plates, takes a large share (Fig. 2).

![Fig. 2 GHG emissions of Fujifilm group in FY2009.](image)

2.2 **Closed Loop Recycling of the PS Plates**

A PS plate is a plate used for printing, and it consists of a high-purity aluminum substrate of 0.15 mm to 0.4 mm thickness, coated with a few micron thick photosensitive layer. Printing is made possible because this photosensitive layer forms images, and because the image area, where the ink should stay, is lipophilic, while the other areas are hydrophobic or oil repelling.

The process of obtaining new aluminum metal by electrolytic refinement from its main raw material, bauxite ore, requires an enormous amount of energy, and the GHG emissions of the process of obtaining 1 kg of primary aluminum metal reaches almost 9 kg. On the other hand, in the case of obtaining 1 kg of recycled aluminum metal, the amount of GHG emissions is just around 0.3 kg, which gives us hope that we can reduce the GHG emissions greatly by using recycled aluminum as raw material. However, production of PS plates requires aluminum with high purity, and it is impracticable to use aluminum recycled from products of lower purity. This is because of the property of aluminum metal that, once it becomes impure, it requires a large amount of energy to purify it again. Therefore, in order to promote the usage of recycled aluminum in PS plate production, it is necessary to change over from the cascade recycling (recycling PS plates for use in other products, Fig. 3), which is currently most common, to closed loop recycling from PS plates to PS plates (Fig. 4).

In October 2006, the FUJIFILM Yoshida-Minami Factory introduced a closed loop recycling system for waste aluminum. The waste aluminum generated in the factory is sorted, foreign matter is removed, and then it is sent to a cooperating metal alloy company where it is melted, producing high purity recycled metal. This high purity recycled metal together with new metal is sent to an aluminum rolling plant to produce aluminum sheets, which are used again in the production of PS plates in the FUJIFILM Yoshida-Minami Factory.

![Fig. 3 Past flow of PS plate aluminum.](image)

![Fig. 4 Present flow of PS plate aluminum.](image)

3. **Standardization Process and Main Features**

3.1 **PS Plates Recycling in the Entire Supply Chain**

In the production stages of printed matter by a printing company, PS plates should be categorized as an “intermediate commodity” at the material procurement stage or at the production stage. However, if PS plates are categorized as an intermediate commodity, the environmental impact of the processes from the mining the raw material to the production of PS plates is considered, which means that the contribution to GHG emissions reduction made by recycling PS plates cannot be evaluated appropriately. Efforts for GHG emission reduction in the design and operation of systems and apparatuses used for exposure and development of PS plates should also be evaluated appropriately. Therefore, we took
the entire life cycle including the usage stage and the disposal and recycling stage of PS plates as the range of items to be evaluated (Fig. 5). This makes it possible to describe the CFP of PS plates in such a way that, when a printing company looks at the CFP of PS plates, they can tell clearly how much contribution to reduction in the final (printed) products is made by the recycling method of the PS plates and how much by the printing company.

3.2 GHG Emission Allocation Method in Recycling Process

For the purpose of clarifying how PS plates are recycled, an example case where 100 kg of aluminum metal for PS plates is used by two printing companies A and B equally, 50 kg each, is described in Fig. 6 and Fig. 7. Here, we assume that the melting loss in producing recycled aluminum metal is 20%.

As shown in Fig. 6, if both of the company A and B use the cascade recycling system, 50 kg of new aluminum metal is consumed by each of them.

On the other hand, if the company B uses the closed loop recycling system while the company A uses the cascade recycling, the company A uses 50 kg of new metal, whereas the company B uses 40 kg of recycled aluminum metal. Here, since we assume the melting loss of aluminum recycling as 20%, out of the 50 kg used aluminum PS plates generated by B, only 40 kg of recycled aluminum metal can be obtained. As a result, 60 kg of new metal is required for the whole system that we are now considering, 50 kg of which is allocated to the company A that uses the cascade recycling, and the remaining 10 kg of which is allocated to the company B. This is equivalent to considering that the disposal/recycling stages of A and B are executed independently.

3.3 Labeling Scheme for the CFP Values

PS plates come in different thickness, length, and width, although those with 0.24 mm thickness are most common. If we label each product with its actual CFP value depending on its size and thickness, the same product will be given different values, which may be confusing for consumers. Therefore, we chose 0.24 mm as the representative thickness of PS plates and use CFP values per unit area in labels. For the products with thickness other than 0.24 mm, the difference in thickness is due to the aluminum substrate since there is no difference in the thickness of the photosensitive layer. Also, the energy required for production of PS plates and the environmental impact of using PS plates in the plate-setting process are uniform. This led us to choose to calculate the CFP values separately for the stages where the amount of GHG emissions is proportional to the weight.

For both company A and B, the ratio is: new metal : recycled metal = 50 kg : 0 kg (100% new metal)

For company A: new metal : recycled metal = 50 kg : 0 kg (100% new metal)
Company B: new metal : recycled metal = 10 kg : 40 kg

For the products with thickness other than 0.24 mm, the difference in thickness is due to the aluminum substrate since there is no difference in the thickness of the photosensitive layer. Also, the energy required for production of PS plates and the environmental impact of using PS plates in the plate-setting process are uniform. This led us to choose to calculate the CFP values separately for the stages where the amount of GHG emissions is proportional to the weight.
of the aluminum substrate (production and circulation of aluminum sheets), and those that where is not (raw materials, production, usage and disposal/recycling of items other than aluminum sheets). Consequently, we could label the products whose thickness is other than 0.24 mm with the GHG emission value of the product that is 0.24 mm thick, with clear markings that state the necessity of conversion according to the actual size and thickness of the products.

In the pilot project directed by the Ministry of Economy, Trade and Industry, it is forbidden to use the official symbol depicting a scale on a product that is categorized as “intermediate commodity” and so does not have its own usage or disposal and recycling stages. This is based on the consideration that they should not be confused by the consumers with products with values calculated in terms of the entire life cycle. The PS plate discussed here was given permission to be labeled with this official symbol because it has its own usage stage and disposal/recycle stage and can be regarded as a “final consumable commodity” for printing companies (Fig. 8, Fig. 9).

In addition, regulations on supplemental information were made to facilitate communication with printing companies. The following can be stated on the labels as supplementary information:

1. Reduction rate of GHG emissions with respect to the previous products
2. Amount of GHG emissions in each stage of the life cycle
3. Ratio of recycled aluminum metal
4. Information regarding the closed loop recycling
5. Weight (kg) per 1 m² (kg)
6. Information regarding the thickness of the product.


In the development of the positive thermal CTP system, the Fujifilm Group reviewed its design with an eye to reducing its environmental impact throughout the entire life cycle, and achieved reduction in GHG emissions by using recycled raw materials and developing a new photo development system.

4.1 Reduction in the Raw Material Stage: the Closed Loop Recycling System of Waste Aluminum

In the case where the closed loop recycling system is not used but instead imported new aluminum metal is used as raw material, the relative contribution by raw material aluminum metal to the GHG emissions of all the production stages of PS plates is as much as 71%. Recycling waste aluminum to produce aluminum metal consumes far less energy than refining bauxite ores into new aluminum metal. Therefore, if recycled aluminum metal produced from waste aluminum is used in place of new aluminum metal, it is possible to reduce GHG emissions generated over all the stages of the PS plate production (from the production of aluminum metal as raw material to that of PS plates) by 63% (Table 1).

In the case of the conventional cascade recycling of aluminum, although it has some effects in reducing GHG emissions in the raw material stages of the products that the aluminum is recycled for, repetition of cascade recycling results in deterioration of the aluminum quality, and also in difficulty in determining the final destination of recycled aluminum, and eventually, the aluminum with deteriorated quality will be discarded. Therefore, the effect of cascade recycling is not included.

<table>
<thead>
<tr>
<th></th>
<th>Aluminum metal</th>
<th>Aluminum rolling process</th>
<th>Raw materials other than aluminum</th>
<th>PS plate manufacturing process</th>
<th>Total</th>
<th>Reduction rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascade recycling</td>
<td>9.22</td>
<td>1.29</td>
<td>0.95</td>
<td>1.59</td>
<td>13.05</td>
<td></td>
</tr>
<tr>
<td>system (100% new metal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PS to PS</td>
<td>0.98</td>
<td>1.29</td>
<td>0.95</td>
<td>1.59</td>
<td>4.81</td>
<td>−63%</td>
</tr>
</tbody>
</table>

* Calculated in compliance with the CFP and PCR of PS plates. The unit is CFP basic unit. The effect of cascade recycling is not included.
recycling is not considered to reduce the GHG resulting from the production stages of PS plates. This is to avoid doubly counting the effect of cascade recycling when it is taken into consideration in the raw material stage of unknown destinations of cascade recycling. The calculation rules for the CFP values adopt the similar principle.

At this moment, the rate of closed loop recycling at the FUJIFILM Yoshida-Minami Factory has reached about 80%. If this rate is increased to 100%, in comparison with the case where only new aluminum metal is used, the amount of GHG emissions will be reduced by up to about 50 thousand tons a year. The accumulated reduction in GHG emissions since the introduction of the closed loop recycling system for waste aluminum has reached about 120 thousand tons (as of 2009).

4.2 Reduction in the Usage Stage: Developer Replenishment Reduction

For our new ECONEX series, we developed the “rapid dispersion developing method” for the plates, which resulted in achieving both developer solution resistance of the non-exposed part and developability of the exposed part. Replenishment solution with high concentration is used to enable the amount of replenishment to be less than that required in conventional systems, while maintaining both sufficient dispersion of developer solution and sufficient image quality. Consequently, the amount of replenishment solution required is reduced by up to 40% in comparison with the previous system.

4.3 Reduction in the Disposal Stage: Reduction of Waste Liquid Disposal

The introduction of the developer/rinse water reduction apparatus “XR” as an option to be used with the automatic image development machine makes it possible to concentrate the waste developer so that 7/8 becomes reclaimed water and the remaining 1/8 becomes concentrated waste liquid. Consequently, the amount of waste developer to be disposed of as industrial waste can be reduced to 1/8.

4.4 CFP Value of ECONEX “XP-F”

As the result of the effect of the closed loop recycling system applied to the waste aluminum generated in the PS plate manufacturing process at the FUJIFILM Yoshida-Minami Factory, together with the improvement in technologies for the image development process and the introduction of developer/rinse water reduction apparatus, the digital thermal plate “XP-F” has achieved reduction in GHG emissions. About a 7.3% reduction in GHG emissions is achieved in comparison with the system prior to the introduction of the closed loop recycling system (assuming that in the prior system, the ratio of new aluminum metal in the raw material is 100%, and that the process and conditions in manufacturing of PS plates are the same) (Table 2).

5. Future Challenges

5.1 From the Perspective of GHG Emission Reduction

Aluminum coils used for PS plates are manufactured at a rolling plant, where both new metal and recycled metal are melted and cast into slabs, which are then rolled into sheets. Therefore, in the current recycling system, two melting processes are required, once for obtaining recycled aluminum metal, and once for casting slabs for rolling. Since the melting is done by burning natural gas and heavy oil, if it is possible to reduce the number of meltings required, it will contribute to reducing GHG emissions.

There are many technical issues to be overcome in order to reduce the number of required melting processes from two to only one. But if it was possible to do so, then the estimated reduction in GHG emissions generated in all the stages of PS plate manufacturing would be potentially about 19% (Table 3).

By expanding the closed loop recycling up to this level, the GHG emissions due to the raw material aluminum in all the manufacturing phases of PS plates can be reduced greatly, lower than the level of GHG emission in the PS plate manufacturing process at the FUJIFILM Yoshida-Minami Factory.

Table 2 Reduction of GHG emissions in life cycle perspective of XP-F. (kg-CO₂e / kg-PS plate)

<table>
<thead>
<tr>
<th></th>
<th>Raw material procurement phase</th>
<th>Manufacturing phase</th>
<th>Circulation and sale phase</th>
<th>Usage and maintenance phase</th>
<th>Disposal and recycling phase</th>
<th>Total</th>
<th>Reduction rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing products (100% new metal)</td>
<td>7.57</td>
<td>1.04</td>
<td>0.16</td>
<td>0.60</td>
<td>0</td>
<td>9.37</td>
<td>—</td>
</tr>
<tr>
<td>XP-F (Closed loop recycling system)</td>
<td>7.05</td>
<td>1.04</td>
<td>0.16</td>
<td>0.44</td>
<td>0</td>
<td>8.69</td>
<td>−7.3%</td>
</tr>
</tbody>
</table>

* Calculated in compliance with the CFP and PCR of PS plates. The unit is CFP basic unit. The effect of cascade recycling is not included.

Table 3 Reduction of GHG emissions in PS plate manufacturing process with one time metal dissolution. (kg-CO₂e / kg-PS plate)

<table>
<thead>
<tr>
<th></th>
<th>Raw material (aluminum coil)</th>
<th>Raw material/other than aluminum</th>
<th>PS plate manufacturing process</th>
<th>Total</th>
<th>Reduction rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting twice (Current system with recycled metal)</td>
<td>2.27</td>
<td>0.95</td>
<td>1.59</td>
<td>4.81</td>
<td>—</td>
</tr>
<tr>
<td>Melting once</td>
<td>1.38</td>
<td>0.95</td>
<td>1.59</td>
<td>3.92</td>
<td>−19%</td>
</tr>
</tbody>
</table>

* Calculated in compliance with the CFP and PCR of PS plates. The unit is the CFP basic unit. The effect of cascade recycling is not included.
5.2 From the Perspective of Resource Efficiency

Generally speaking, the ratio of bauxite to the aluminum obtained by refining the bauxite is four to one. The remaining three quarters become strongly alkaline, highly toxic waste substance called red mud. The only way to dispose of this red mud is to pump it into a holding pond, which implies the need for external cost. In October 2010, in Hungary, the bank of one such holding pond broke and the red mud from this pond flooded into the surrounding rivers and towns, causing grave concerns about the damage it may have caused on ecological systems. Promotion of the closed loop recycling system is important not only from the point of reducing the huge amount of energy required for electrolytic refinement in the manufacturing process of new aluminum metal, but also from the point of reducing the amount of red mud generated in the process and of making better use of resources that are of limited availability. The current material flow of aluminum in Japan forms a very complex system established on the basis of the purity and the application. However, in the final count, there is quite a large shortage due to accumulation in “urban mines” or being sent overseas, requiring constant addition of new metal in the system.

In order to evaluate the significance of the closed loop recycling system, we used a simplified model of the material flow (a model for the comparison between the case where the cascade recycling system is 100% used and the case where the closed loop recycling system is 100% used) (Fig. 10, Fig. 11). In the transition phase from the cascade recycling system to the closed loop recycling system, it is inevitable that some leakage of new metal would occur (e.g. when the use of new metal is stopped for one application, but started anew for some other application). However, we should not be concerned about this too much; otherwise, we will get a distorted view of the system that we aim to reach in the long term.

What we should achieve through the closed loop recycling system is to circulate metal among like products with the same aluminum purity. And, ideally, while doing so, the amount of new aluminum metal is added to the system is kept to the minimum, aided by monitoring the demand and supply balance of each product.

This is a goal that is difficult to achieve in a short period. However, as a company that produces PS plate, a product that requires aluminum with more than 95% purity which positions it at the very top of the cascade recycling chain, it is our mission and social responsibility to take the lead in reaching this goal.

6. Conclusion

Further promotion of the closed loop recycling system of PS plates is not attainable by our company’s efforts alone, and cooperation from our stakeholders, in particular printing companies, is indispensable. In order to develop a system to achieve GHG emission reduction and resource circulation in the entire supply chain, we hope to exploit the CFP labeling scheme as an effective communication tool.

References

2) General principles for the assessment and labeling of Carbon Footprint of Products, TS Q 0010 (2009).

(In this paper, “ECONEX” is a registered trademark of FUJIFILM Corporation.)
Postscript

We bring out this publication every year to introduce our new products, the technology featured therein, and some of fundamentals concerning the research underpinning the development of our products, which represent the pinnacle of our research and development activities. In order to provide an overview of such wide-ranging research and development activities across numerous business fields, ten original papers were selected and published this year from amongst our diverse research and development results focused on cosmetics, diagnostic imaging systems, image processing technology, software technology, and advanced functional materials for printing, semiconductor manufacturing and data storage, etc., while a dozen papers were selected from amongst those recently published in various science and technology journals. Besides this selection, numerous technological findings were publicized through presentations at academic conferences and contributions to scientific journals, thus contributing to the advancement of science and technology, and these are listed at the end of this publication. We would be thrilled if the efforts of our research and development to demonstrate “creativity, activeness, and cohesion” so as to achieve new growth, while aiming for real improvements in the quality of life, are felt.

(Editor in Chief : Yoshio Inagaki)