

# Development of New Extra-large Size Micro Filter Cartridges and Housings

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## Abstract

FUJIFILM has manufactured and marketed micro filters, the AstroPore series, for about 30 years. Our micro filters are used in various manufacturing processes such as filtering miscellaneous germs from foods (draft beer etc.), manufacturing liquid crystal panels, etc. These days, various filters are used in the rapidly growing market of liquid crystal panels. With the size of panels (screens) becoming larger, a more productive filtration system is required to increase productivity during manufacturing processes. Although our proprietary technology applied to the production of asymmetric polysulfone membranes with an internal dense layer provides them with characteristics to fulfill most demands from the market by themselves, we developed and introduced the extra-large size micro filter cartridges and their housings to meet even stricter demands from production sites. This technology is summarized in this paper.

## 1. What are micro filters?

### 1.1 Introduction

Though you may be surprised to know, filters are used in almost every aspect of our daily lives. They can be found in various appliances we use daily, such as tap-water purifier, air-conditioner, vacuum cleaner, air purifier and the air inlet of AV equipment for the removal of dust. In high-technology areas, meanwhile, various types of filters are widely used depending on the purposes of their use. For example, filters are used in the artificial dialysis of kidney in medical field, for manufacturing mineral water, pure sake and draft beer in the drinks field and in the recent electronics industry including the field of semiconductor manufacturing.

Our company started manufacturing micro filtration filters about 30 years ago. Especially, the cartridge filter using polysulfone (PSE) membrane that was placed on the market in 1987 has won favorable recognition, due to its unique filtration performance, from many production sites of food, precision equipment, chemical, and electronics industries.

In recent years, the electronics industry tends to request more precise filtration capability for cartridge filters. The demand for the development of cartridge filters capable of meeting this kind of request has been growing.

## 1.2 Classification and Positioning of Micro Filter Cartridges

### 1.2.1 Classification of Filters

There are many kinds of filters used for a great variety of purposes. In general, they can roughly be classified as follows:

- (1) Classification by the type of dispersion medium and solvent:  
Gases or liquids (in addition, aqueous/chemical solution system)
- (2) Classification by the size of dispersed particles and solutes:  
Coarse filtration, micro filtration, ultra filtration, nano filtration and reverse osmosis filtration
- (3) Classification by shape:  
Disk, cartridge, hollow fiber, etc.

The micro filters of our company introduced this time are designed for (1) Liquids, mainly aqueous system, categorized as the level of (2) Micro filtration, and (3) Cartridge type.

First, the definition of micro filtration will be explained here. As the methods for the separation of fine particles, there are the micro filtration, ultra filtration and reverse osmosis filtration. The micro filters mentioned above belong to the category of micro filtration. According to JIS K3802, micro

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filtration membranes are defined as "membranes capable of separating fine particles and germs of about 0.01 to several  $\mu\text{m}$ " (Table 1).

Table 1 Filters Classified by Sizes of Particles to be Filtered.

Filtration method	Micro Filtration	Ultra Filtration	Reverse Osmosis
Abbreviation	MF	UF	RO
Size	Several $\mu\text{m}$ - 0.01 $\mu\text{m}$	0.1 $\mu\text{m}$ - 5 nm	<5 nm
Items to be filtered	Fine particles, germs	Molecules	Ions

### 1.2.2 Further Classification of Micro Filters

From the viewpoint of the size of particles separated from micro filtration membranes, the trapping performance and structure, micro filters can be further classified into the absolute type (absolute filtration type) and the nominal type (nominal filtration type).

The absolute type filters are filters "that can literally completely trap particles larger than the designated size." They are generally characterized by their sieve-like structure in which many small pores are formed in a sheet of resin membrane. Utilizing the effect of this sieve-like structure, they can separate particles larger than the size of those pores (Fig. 1).

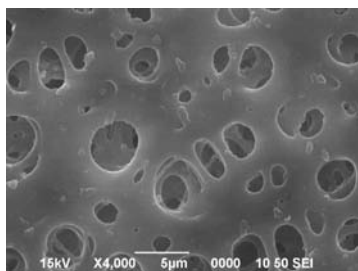


Fig. 1 Photo of the surface of standard absolute type (FUJIFILM PSE membrane).

On the other hand, the nominal type filters have a structure composed of tangled fibers (Fig. 2). In the case of the nominal type filters, besides the filtration of particles by the physical size of their filter fibers, they filtrate particles by adsorbing them on their filter fibers using adsorption effects such as hydrophobic interaction, hydrogen bonding or ion interaction. For this reason, the absolute value of filtration size changes depending on the type and physical properties of particles. The size range of particles to be filtered also becomes wider compared with that of the absolute type filters.

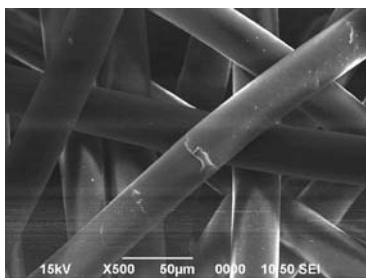


Fig. 2 Photo of the surface of standard nominal type (non-woven PP material).

Our company's polysulfone (PSE) membrane is categorized as the absolute type, which can completely trap particles larger than its pore size. To date, our company has been conducting business by mainly selling the micro filter cartridges, the AstroPore series, which use the unique PSE membrane.

In the field of micro filtration mainly for aqueous system, the products have been favorably accepted by users due to their unique filtration performance.

## 2. Background in the Development of PSE Extra-large Size Micro Filter Cartridges and Housings

### 2.1 Market Situation

The electronics industry of manufacturing such items as liquid crystal panels and semiconductors has been rapidly growing at an annual growth rate of about 10 percent. In these manufacturing fields, the technological progress has increased the demand for more precise and cleaner production environments. As a result, it is becoming common to apply precise washing to the individual manufacturing processes. Micro filters are widely used in the preparation of ultra-pure water required for such precise washing processes.

In the production field of liquid crystal panels, their production amount and the size of panels are significantly increasing recently. This is partly because the generation is fixed according to the size of glass. For example, the size (area) of glass panels has increased by more than five folds in about the past five years (Table 2).

Table 2 Change of Glass Sizes for Liquid Crystal Panels.

Generation	Glass size	Starting year
G4	680 x 880 (mm)	2000
	730 x 920 (mm)	
G5	1000 x 1200 (mm)	2002
	1100 x 1300 (mm)	
G6	1500 x 1850 (mm)	2003
G7	1870 x 2200 (mm)	2005
G8	2200 x 2400 (mm)	2006
G9	2400 x 2800 (mm)	2007

In addition, a manufacturing plant called G10 (3000 x 3000 (mm)) is in the planning stage. This trend will likely continue for a while.

This expansion of manufacturing facilities has resulted in the significant increase in the use of ultra-pure water. For this reason, the demand for micro filtration cartridge filters with higher flow rates is becoming stronger. Especially in the manufacturing of panels after the G7, it is required to obtain a flow of as much as 200 l/min per washing water filter. At the same time, the demand for micro filtration cartridge filters capable of completely trapping particles (fine foreign matter) has been growing.

## 2.2 Problems of the Existing Micro Filtration Cartridge Filters

There have been no micro filters that could satisfy the high flow rate and higher trapping performance required by micro filtration cartridge filters to be used in the manufacturing processes of liquid crystal panels after the G7.

Of our company's micro filter cartridges, the large-sized high-flow PSE cartridge XL type has the highest flow-rate performance but its flow-rate value is 150 l/min, which cannot meet the above-mentioned target value when it is only used. Even the other companys' large sized micro filter cartridges that are compatible with our XL type are unable to achieve a flow rate of 200 l/min when the individual cartridge is only used, indicating that they cannot meet the requirement of manufacturing processes for panels after the G7 (Fig. 3).

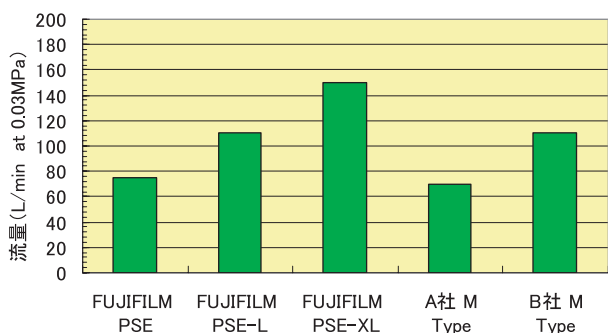


Fig. 3 Flow rate characteristics of micro filter cartridges.

In the meantime, it will be required to increase the flow rate further, perhaps up to 300 l/min, in order to meet the manufacturing processes for panels after the G8 and G9 drive-started from the year of 2007.

In a manufacturing process, if more than one filter cartridge are used together, it may cause some disadvantages such as the necessity to use a larger housing (waste of space) or the increase of labor for their exchange. Therefore, the development of much larger filters was considered essential.

From this viewpoint, we have started development activities to produce extra-large size micro filter cartridges and their housings, which would be able to meet the conditions required for the manufacturing lines of liquid crystal panels after the G7.

## 3. Development of Extra-large Size Cartridges

### 3.1 Technical Characteristics of AstroPore Series PSE Membrane

First, the unique filtration performance of micro filter cartridges using AstroPore series PSE membrane will be explained briefly. The material of the PSE membrane is polysulfone as shown below (Fig. 4).

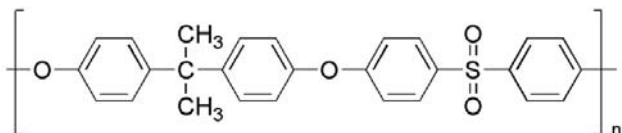


Fig. 4 Structural formula of polysulfone.

Our company's micro filters are porous membrane filters, which is made of this polymer and prepared by using a phase separation method. By fully utilizing our company's unique membrane manufacturing technology, it becomes possible to prepare the membrane having a dense, characteristic pore distribution. Our company's AstroPore series PSE membrane is characterized by its pore distribution. (Fig. 5).

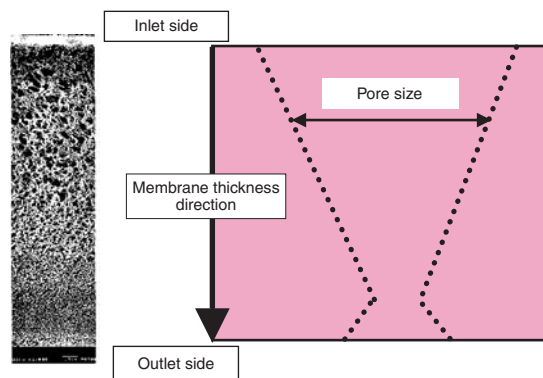


Fig. 5 Photo of cross section and schematic diagram of pore distribution of the AstroPore series' PSE membrane.

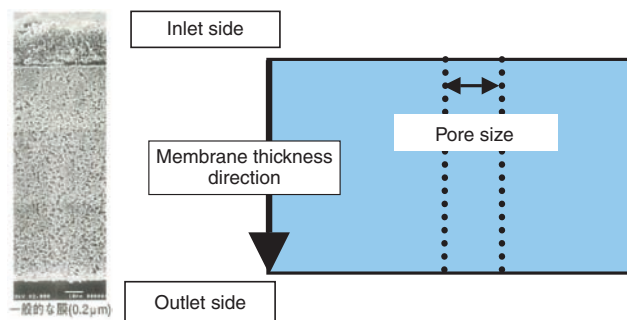


Fig. 6 Photo of cross section and schematic diagram of pore distribution of an ordinary micro filter membrane (the same pore diameter).

The most important characteristic of AstroPore series PSE membrane is that the size of small pores existing in the porous layer is distributing asymmetrically. As is apparent from the figure, the pore size is the largest in the inlet side into which fluid such as water flows and gradually becomes smaller as the depth increases. Because the effective filtration area that determines filtration accuracy is formed as a dense layer inside the membrane, it can have the following unique performances:

#### (1) Excellent flow characteristics

As can be calculated from Poiseuille's law\*, the effective filtration area exists as a dense layer having a short passage. For this reason, it becomes possible to flow more fluid at a lower differential pressure compared with a membrane having the uniform pore-size distribution.

\* Poiseuille's law:  $V = (\pi Pr^4) / (8\eta l)$

Where, V=permeated amount, P=pressure, r=pore diameter,  $\eta$ =viscosity I=pore length

(2) High trapping performance

Fig. 7 shows the pore-diameter distribution in the dense layer.

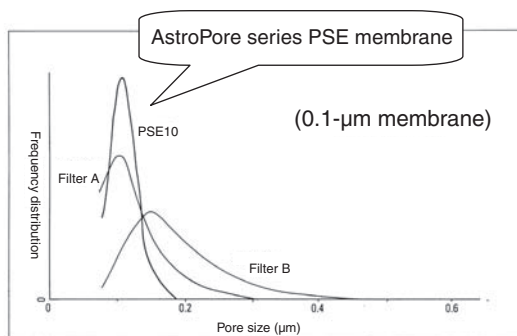


Fig. 7 Comparison of pore distribution at 0.1µm membrane.

As is apparent from the figure, the pore-diameter distribution is very sharp. Therefore, it is possible to precisely separate particles into a specific pore size range.

(3) Very long cartridge life

In a membrane having a uniform pore-size distribution, as the dense layer exists in the surface of the inlet side, a blockage occurs on the surface of filter very quickly. Meanwhile, AstroPore series membrane can trap particles with varied sizes in different areas in the depth direction. For instance, large particles can be trapped in the large-pore area. Its outlet side plays a role in protecting the dense layer or can resist the mechanical stress.

### 3.2 Scale-up of Cartridge Filters

To increase the flow rate of cartridge filter, it is a common way to increase the size of cartridge and the area of membrane used for it. This time, there was a choice to develop a new filter membrane. However, considering that FUJIFILM AstroPore series PSE membrane was unique and excellent, it was decided to examine the possibility of increasing the cartridge size and the area of membrane used for it.

As mentioned above, the AstroPore series PSE membrane has excellent permeability, flow rate, filtration life and durability.

#### 3.2.1 Development of Extra-large Cartridge

For the scale-up of filter cartridge, the “square-cube law” becomes important in general. The aim to increase the cartridge size is to increase the filtration area as much as possible. However, the overall volume or weight of cartridge, rather than filtration area, tends to increase more according to the “square-cube law”.

Cartridge size was designed at the request of user. When the condition such as pressure is constant, the volume of fluid passing through filtration membrane is generally proportional to the area of the filtration membrane. It was a problem how to secure the effective filtration area and obtain high flow rates with that cartridge size.

In this study, we took notice of the processed shape of filter membrane to be installed inside a cartridge filter in order to increase the effective filtration area of PSE membrane to be used. In the case of a micro filtration cartridge filter, a filter medium is sandwiched between at least two supporting materials (from its upper and lower sides) and the resulting medium is processed into pleat shape so that the medium having a membrane area as large as possible can be accommodated in the cartridge (Fig. 8). This time, we have examined this pleat technology and employed a method capable of increasing the height of the folded part of pleated filter medium by about twice higher than that of the conventional product.

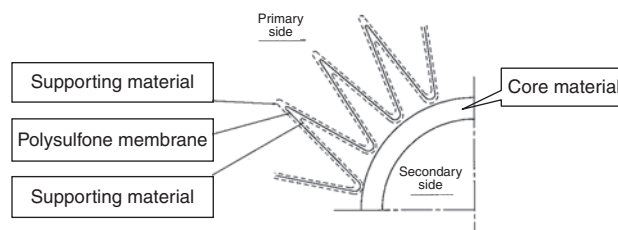


Fig. 8 Rough structure of cartridge filter.

If the height of folded part is increased, it is more likely to have a problem that the pleated shape becomes unstable in the process where a filter is folded to have a pleated shape. By reviewing the items shown below, we have succeeded in establishing a pleat technology that could provide stable and uniform pleated filters.

Selection of supporting material

Increase of accuracy in the transport control of filter medium and supporting material

Optimization of processing conditions for pleat processing

Table 3 summarizes the lineup and representative performances of the high-flow rate, compact, extra-large size micro filter cartridges PSE-UXL/SXL that have been developed this time. As expected, a single unit of this filter cartridge can provide a flow rate of more than 200 l/min.

Table 3 Specifications of Extra-Large Size Micro Filter Cartridges.

Product type	PSE-SXL	PSE-UXL
Total length (mm)	273	273
Outer diameter (mm)	130	130
Pore size (µm)	0.1, 0.2, 0.45, 1.2	
Flow rate (L/min)*1	200	300

\*1: Initial flow rate (representative value) when water was passed through the cartridge filter with a pore size of 0.2 µm (PSE-SXL/UXL) at a differential pressure of 0.03 MPa

### 3.2.2 Development of Housings for Extra-large Size Cartridges

For the extra-large size cartridges, their housings were also developed. Table 4 shows the lineup of the housings.

Table 4 Lineup of Housings for Large-Size Cartridges.

Product type	Extra-large size resin housing FPSUX E 1	Extra-large size metal housing FS6LJM 1-1 50 FET 1
Designed pressure	Max 0.49 MPa	Max 0.97 MPa
Designed temperature	Max 50°C	Max 100°C
Material	Body: Polypropylene	Body: SUS316L
Piping system	40A, 50A, 65A	50A

To make the product more eco-friendly, polypropylene was used for the main body of the housing for use in normal aqueous system. In addition, to expand the versatility of the housing, three kinds of piping joints were made available, which would cover the extra high flow rate (65A) and normal high flow rates (40A and 50A). Moreover, to cope with extra high flow rates, the housing was designed to be able to resist a pressure of up to 0.49 MPa.

The housing made of stainless steel was made available to cope with chemicals as well as high temperature and pressure lines. The stainless steel used is SUS316L that has excellent durability, so that the housing can be used in the latest facilities.



Fig. 9 Extra-large size micro filter cartridge PSE-UXL.



Fig. 10 Housings for extra-large size cartridges (left-hand side: extra-large size resinous housing, right-hand side : extra-large size metal housing).

## 4. Conclusion

The extra-large size micro filter cartridges and housings that have been described in this paper are fully utilizing the features of our company's AstroPore series PSE membrane such as the excellent flow-rate property, trapping performance and long life. They can display the excellent filtration performance at incredibly high flow rates in the manufacturing processes of liquid crystal panels after the G7.

Finally, we must thank all the people who kindly instructed and helped us in developing the products.

## References

- 1) Jun Sasaki; Kyoichi Naruo. FUJIFILM Corp.. Fine Porous Membrane. Japanese Patent Publication No. 4-68966. 1992-11-4.
- 2) JIS K3802 Technical terms for membranes and membrane processes.

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