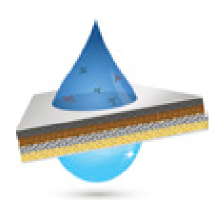
Eastman cellulose esters for **membrane filtration**

Filtration has become an integral process in nearly every facet of our lives. Our homes and offices have HVAC systems that feature sophisticated filters. Our vehicles have systems to filter air, oil, and gas. Dairies prepare their products using filtration. And beers, wines, and fruit juices are clarified using membrane filters.

Filtration can broadly be described as separating one substance from another. Engineering effective filtration membranes can pose unique challenges. Membrane manufacturers are searching for the right ingredients to balance their need to create high-quality membranes with production requirements that include faster line speeds and lower defect rates.



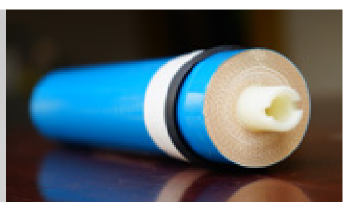
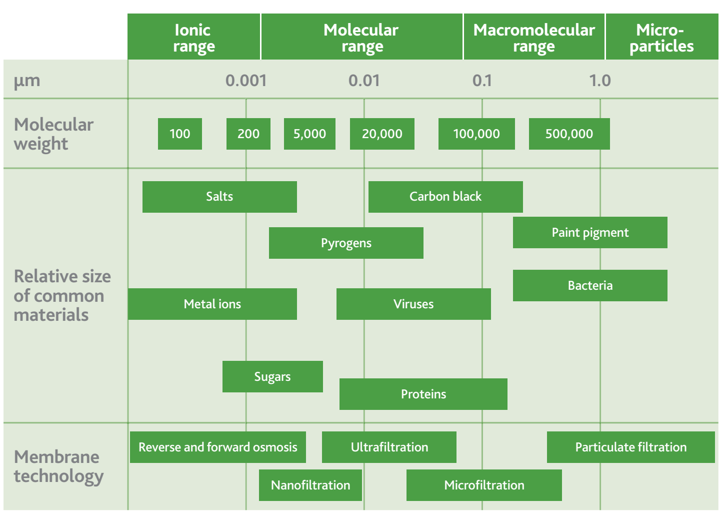


Figure 1 provides a general overview of which membrane process is needed for a variety of separations based on the size of the molecule or substance that is to be removed.

Figure 1. Filtration overview



Eastman cellulose esters (CEs) have been used in the manufacture of membrane filters for many decades. In 1947, Eastman Kodak was granted a patent on an asymmetric hemodialysis membrane based on a mixture of polyvinylpyrrolidone and cellulose acetate. Over the decades, CEs have been used effectively in many different membrane filtration systems, including microfiltration, ultrafiltration, nanofiltration, reverse and forward osmosis, and gas filtration. Eastman offers a wide range of cellulose ester compositions in our M-series products to fine-tune desirable filtration properties, including water flux, salt rejection, and solubility parameters. In addition, these products are available for use in applications that require food-contact compliance. This versatility of choice helps formulators achieve their production and performance goals.

CE properties

For most membrane filtration applications, cellulose acetate (CA) is the most frequently used cellulose ester, although cellulose acetate propionates (CAPs) and cellulose acetate butyrates (CABs) have also been investigated.

Products can be used neat or blended as required to achieve desired performance.

Table 1. Properties of Eastman M-series cellulose esters

Property	Regular and food contact grades			
	M203	M210	M230	M300
T_g, °C DSC	182	185	189	172
Water uptake, %	17	17	17	11
Surface energy wet, dynes/cm	48	47	47	46

Note: *Water uptake was calculated from weight increase after submerging a film in water for 120 hours at room temperature.*

Applications of Eastman CE membrane materials

Reduction of fouling in ultrafiltration and microfiltration

Membrane fouling is a common problem in ultrafiltration (UF) and microfiltration (MF), causing poor flow and performance and reducing membrane service life. Cellulose acetates have been used to modify the hydrophilicity of hydrophobic polymers such as polyvinylidene fluoride (PVDF) membranes used in UF and MF, making the membrane surface more hydrophilic. This allows better contact with the aqueous feed stream and a reduction in fouling. Data in Table 1 show that water uptake creates relatively high surface tension, reducing fouling.

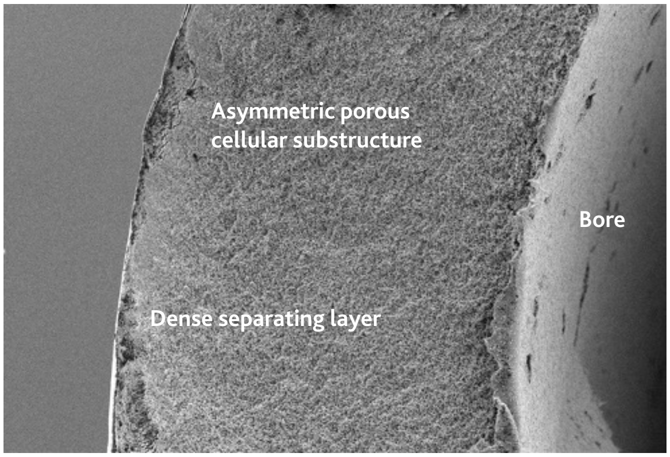
Reverse osmosis

M-series cellulose esters are used in hollow-fiber reverse osmosis (RO) membranes and some wastewater and food and beverage RO applications where fouling problems due to high suspended solids are more common.

In natural gas filtration, M-series polymers show inherent selectivity for CO_2/CH_4 of 20–25. In this application, both spiral-wound and hollow-fiber (HF) modules are in commercial use. In some applications, cellulose esters are modified to allow cross-linking, reducing plasticization by the acid gases.

Cellulose esters can produce an open, porous substructure, allowing fast transport in both flat sheet for spiral-wound modules and HF membrane modules. Figure 3 shows a micrograph of an asymmetric HF membrane cellulose ester.

Figure 3. **Asymmetric hollow-fiber membrane CE**



Forward osmosis

Cellulosic membrane materials from Eastman are also used in forward osmosis (FO) membranes in both industrial applications and food and beverage concentration. The family of cellulose esters produced by Eastman for membrane applications are high-purity with a very consistent viscosity. These versatile materials are used in a wide range of FO applications, from personal hydration devices to concentrating juices and nutritional supplements to recovering fresh water from highly polluted effluents. In these applications, the antifouling properties of cellulose esters are very important.

Eastman cellulose esters have been used in various FO membrane formats, including spiral-wound modules, plate and frame, hydration pouches, and hollow fibers.

Figure 4. **Example of an osmosis module**

When used for liquid streams with high levels of organics or scaling minerals, water-removal membranes can foul easily. Also, when concentrating food or beverages, thermal evaporation can negatively affect key flavors. In these cases, FO is an excellent method to dewater such sensitive or high-fouling streams. The draw solutions that drive the FO process are often regenerated with RO in tandem with FO.

Membrane manufacturing considerations

A common manufacturing method for membranes is through phase inversion. The membrane is formed by casting a cellulose ester solution in a solvent (e.g., acetone or NMP) on a porous backing material while controlling the dope thickness with a doctor blade. The next step is introducing it into a nonsolvent inversion vessel, forming the desirable structure. In some cases, the membrane is treated with a caustic solution to hydrolyze all the acyl groups back to hydroxyl groups. The final membrane product is now a regenerated cellulose membrane that has a targeted morphology to meet desired filtration targets but is hydrolytically more stable. This stability is important in food and dairy applications where harsh cleaning procedures using acids and bases are routinely performed.

As demonstrated in Table 2, cellulosic derivatives are especially advantageous when filtering process streams that are highly fouling. In addition, it is a more economic option than alternative polymers.

Table 3. General comparison of polymers commonly used to make membranes

Material	pH range	Cost	Tensile strength, mPa	Oxidant resistance, ppm hours of chlorine	Other strengths and weaknesses
M-series cellulosic derivatives	Narrow, 4–9	Low	Moderate, 30–60	High, $>10^4$	**Strengths:** High fouling resistance; low cost; highly hydrophilic **Weaknesses:** Lower flux rates; limited pH range
Polyamides	Wide, 2–11	High	High, 130–150	Low, <500	**Strengths:** High mechanical strength; very high rejection level **Weaknesses:** Destroyed by chlorine; prone to biofouling
Fluorinated polymers (PVDF)	Moderate, 2–10	High	Moderate, 30–60	High, $>10^4$	**Strengths:** Chlorine resistant; moderate to high rejection level **Weaknesses:** High cost; difficult to produce; hydrophobic
Polysulfone and polyester sulfone	Wide, 1–13	Moderate	Moderate to high, 70–90	Moderate, $<10^4$	**Strengths:** High rejection level; wide pH range; high temperature resistance **Weakness:** Limited tolerance to chlorine

Summary

Membrane manufacturers have relied on Eastman cellulose esters to manufacture high-quality membranes via efficient production processes for nearly 80 years. Today, Eastman offers M-series materials specifically for this market in industrial applications and food and beverage filtration processing.

Eastman membrane material M300 is a high-purity cellulose derivative with a very consistent viscosity. Eastman membrane materials M203, M210, and M230 have increasing molecular weight. All are highly filtered and screened throughout the manufacturing process and offer the versatility formulators need to produce high-performing membranes.

These four cellulosic polymers can also be supplied as separate products with FDA approval for food contact in food or beverage processing applications and are labeled with the suffix “food contact.”

Eastman has significant technical expertise in research and development, including blending of M-series materials to obtain the targeted membrane functionality.

For help determining the best Eastman M-series cellulose esters for your filtration application, contact your Eastman technical representative or your authorized Eastman distributor.

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