Fabrication of mosaic nanofilters for molecular transport, separation of macromolecules

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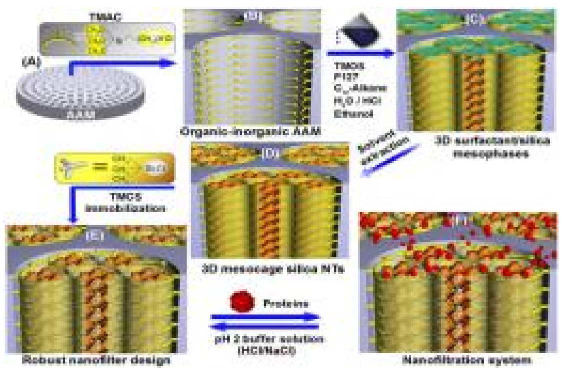

Fig. 1 Robust, simple synthesis process for nanofilter AAM membranes in 3D mosaic cage silica NTs for molecular orientation and size cut-off of proteins. Note: The abbreviations used are N-trimethoxysilylpropyl-N,N,N-trimethylammonium chloride (TMAC), tetramethylorthosilicate (TMOS), and trymethylchlorosilane (TMCS).

A team led by Dr. Sherif El-Safty, Exploratory Materials Research Laboratory for Energy and Environment, National Institute for Materials Science (NIMS; Japan), fabricated tight mosaic cage silica nanotubes (NTs) inside anodic alumina membranes (AAM) as a promising candidate nanofilter for high-speed (within several seconds) size-exclusion separation of high concentration macromolecules.

To date, separation of proteins into relatively homogeneous groups and sizes has been very important in biopharmaceuticals and medicines. From the practical viewpoint, the requirements for these applications include easy scaling-up, fast separation, suitability for high production volumes, and low cost. Technically, the design of extremely robust filter membranes without formation of air gaps among membrane nanochannels is a remaining challenge, as pore gaps not only reduce the potential of size-exclusion nanofiltration systems, but also limit the long-term storage stability of NTs, making storage difficult even for a month.

For practical control of mosaic nanofilter membranes, a general approach based on densely engineered three-dimensional (3D) mesocage structures inside silica NTs was adopted. In this design, multifunctional surface coating of the pore channels of the AAM facilitated production of extremely robust constructed sequences of membranes as “real nanofilters” without “detachment pores” (air gaps) between the fabricated nanotubes inside the AAM. The approach used by the NIMS team is ideal for constructing tubular-structured architectures inside membranes with vertical alignment, open surfaces of top-bottom ends, multidirectional (3D) pore connectivity, and stability, which are promising for application to nanofilter systems.

The key to this development was the fact that the nanofilter system efficiently separates macromolecules such as proteins of various sizes over a wide, adjustable range of concentrations. Although conventional processes require as much as 12 hours or more, this technique provides a rapid filtration process that achieves filtration in seconds, despite the blocking effect of the proteins during the filtration process.

The intrinsic properties of the NIMS design (shelf-life or long-term stability, separation efficiency, reusability) are important advantages in comparison with the conventional protein nanofilter techniques used to date. Such advantages will be key to the development of a fabrication approach with the potential to become the optimal method for the design of nanofilters for filtration and molecular transport of multiple species.

The results of this research demonstrated that the NIMS approach offers a time- and cost-efficient alternative tool to current macromolecule analysis methods. This development also offers new insights into control design of devices in the fields of electronics, sensors, and other nanotechnologies.

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