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Commentary

Inorganic Membrane Technology and Classification

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DESCRIPTION

Inorganic membrane science and technology is a promising area of membrane separation technology that has been dominated by polymer membranes. The inorganic membrane has seen remarkable progress and invention in recent years. Alumina, titanium, zirconia, different oxides, ceramic, carbon, silica, and zeolite are examples of inorganic materials that can be used to make membranes, as well as metals like palladium, silver, and their alloys. Based on their structure, inorganic membranes can be divided into two main groups: porous inorganic membranes and dense (non-porous) inorganic membranes. Amorphous and crystalline membranes both are types of micro porous inorganic membranes. They have two different structural types: Symmetric and asymmetric. By smearing a colloidal solution is known as sol onto a porous support, it is possible to create micro porous inorganic membranes. The sol might be made up of polymeric macro molecules or dense, spherical particles (colloids of oxides like Al_2O_3, SiO_2, or ZrO_2). Although inorganic membranes are more expensive than organic polymeric membranes, they have the advantages of being sterilizable, having a well-defined stable pore structure, and being resistant to solvents.

Long-term stability at high temperatures, tolerance to hostile environments, resistance to high pressure drops, inertness to microbial destruction, ease of cleaning after fouling, and ease of catalytic activation are some of the advantages of inorganic membranes over polymeric membranes. Inorganic membranes were excellent candidates to be employed in water treatment and desalination applications because of all of these exceptional qualities. High capital costs, brittleness, low membrane surface per module volume, difficulty in achieving high selectivity in large-scale micro porous membranes, typically low permeability of the highly selective (dense) membranes at low temperatures, and challenging membrane module sealing at higher temperatures are a few of the drawbacks of inorganic membranes. The main purpose of using dense inorganic membranes is to separate gases with extreme precision, such as hydrogen and oxygen.

CLASSIFICATION BASED ON MATERIAL TYPE OF INORGANIC MEMBRANE

Metal membrane

It is being investigated to separate hydrogen from gas mixtures by using dense metal membranes. Palladium (Pd) and its alloys are most commonly used materials due to their high hydrogen solubility and permeability. However, palladium is very pricey. An approach is to coat a tantalum or vanadium support film with a thin palladium layer. Tantalum and vanadium are alternatives to palladium that are less expensive and also quite permeable to hydrogen. Thin metallic membranes with support have recently received attention. Reduced material costs, increased mechanical strength, and perhaps higher flux are some of the benefits. Production of composite palladium membranes for use in Catalytic Membrane Reactors (CMRs) has been the key advancement.

The concept of intensification, on which this advancement is established, has several key components, which is the potential to combine the reaction and separation stages of a method into a single unit. The Catalytic Membrane Reactors (CMRs) is one such application. Along with the inherent benefits of lower plant and maintenance costs, increased conversion rates and product yields may also be possible. A thin coating of palladium or a palladium alloy is placed over a porous substrate, like ceramic or stainless steel, to create the composite palladium membrane utilized in the CMR. The composite palladium membrane is positioned next to a catalyst bed and works to remove hydrogen from the catalyst reaction source in a selective manner. These membranes can also be used to regulate the feed rate during partial oxidation reactions (e.g., the addition of hydrogen). The consequences of surface poisoning caused, (for example, by a carbon-containing source), which might be more severe for thin metal membranes, are a key issue with metal membranes.

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Ceramic membrane

Ceramic membranes are made up of either aluminum or titanium metal (oxides, nitride, or carbide). Due to their uncontrolled, they are typically used in extremely acidic or basic situations. Ceramic microfiltration and ultrafiltration membranes are particularly well suited for the food, biotechnology, and pharmaceutical industries due to their resilience, as these industries frequently steam purify and chemically clean their membranes. For gas separation, ceramic membranes have also been suggested. Ceramic membranes' great sensitivity to temperature gradients, which causes membrane cracking, is a drawback. The benefit of the membrane-based process is that it produces syngas in a single step on one of the membrane sides, negating the need for a separate facility for producing oxygen and perhaps resulting in much lower energy and capital costs.

Carbon membranes

In terms of separation characteristics and stability, Carbon Molecular Sieve (CMS) membranes have been discovered as particularly promising candidates for gas separation. Carbon molecular sieves are porous materials with limited pores that are similar in size to the molecules of diffusing gas. As a result, molecular sieving can successfully separate molecules with very modest size variations. There are two types of carbon membranes: Supported and unsupported. While supported membranes only come in two configurations—flat and tube—unsupported membranes come in three: Flat (film), hollow fiber, and capillary. Many thermosetting polymers, including poly (vinylidene chloride, or PVDC), poly (furfural alcohol, or PFA), cellulose triacetate, polyacrylonitrile, or PAN, and phenol formaldehyde, can be pyrolyzed to produce CMS membranes.

Zeolite membranes

Due to their highly consistent pore size, zeolite membranes are used in highly selective gas separation. Additionally, this substance exhibits catalytic properties, which are advantageous for applications involving catalytic membrane reactors. In the form of micron-or submicron-sized crystallites contained in millimeter-sized granules, zeolites are used as catalysts or adsorbents. The most popular zeolite for use as a membrane is MFI. The main issue is relatively low gas fluxes compared to other inorganic membranes. Due to the fact that relatively thick zeolite layers are needed to get a pinhole-free and crack-free zeolite layer. Overcome this by using a thin layer supported by others. The thermal impact of zeolites is another issue. The zeolite layer has the potential to experience negative thermal expansion, which means that at high temperatures, the zeolite layer contracts.