MEMBRANE DEVICE AND PROCESS FOR MASS EXCHANGE, SEPARATION, AND FILTRATION

CROSS REFERENCE TO RELATED APPLICATION

This is a Non-Provisional application that claims priority from U.S. Provisional Application No. 61/768,124 filed 22 Feb. 2013 entitled "Membrane Device and Process for Mass Exchange, Separation, and Filtration", which reference is incorporated in its entirety herein.

STATEMENT REGARDING RIGHTS TO INVENTION MADE UNDER FEDERALLY-SPONSORED RESEARCH AND DEVELOPMENT

This invention was made with Government support Contract DE-AC05-76RL01830 awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

BACKGROUND OF THE INVENTION

Low-cost, high surface area inorganic membrane modules have been long sought by industry because of unique performance attributes of both metallic and ceramic materials. In order to be easily deployed, membrane modules need to include a compact form. Conventional reverse osmosis (RO) membranes packed with polymer membranes can provide a large membrane surface area per unit volume. However, reverse osmosis (RO) membranes are ineffective for mass transfer applications due to an inability to process sweep (i.e., gas) flow streams. RO-type membranes with their cylindrical designs are also limited by channel dimensions that can lead to large pressure drops when placed under vacuum. In addition, conventional filters that employ metal or ceramic tubes have a membrane packing density that is typically lower than polymer membranes by nearly one order of magnitude. In addition, spiral-wound RO membrane filters and plate-type RO membrane filters commonly used for desalination of sea water and for treatment of waste water in bio-reactors, respectively, provide filtration of only a single flow stream in a single flow direction. Neither filter can process dual flow streams simultaneously, which eliminates mass transfer and heat transfer between two flow streams. And, membrane filters designed for liquid-phase filtration are not suitable for vapor-phase separation at low pressures or under vacuum where pressure drops become a significant concern. Accordingly, new membrane designs are needed that provide high mass transfer rates with minimal pressure drops for liquid and vapor-phase separation and filtration applications. The present invention addresses these needs.

SUMMARY OF THE INVENTION

The present invention includes a membrane device that finds applications in mass-exchange, mass-transfer, heat-transfer, separation, filtration. The membrane device may include one or more membrane cassettes that are stacked together to form a membrane module. Each membrane cassette may include a support frame constructed of a selected material (e.g., metal or plastic). Porous metal sheet membranes may be mounted to respective sides of the support frame. The membrane cassettes in the stack provide

a number of feed flow slots and permeate (or sweep) flow slots on respective sides of the membrane device with flow channels that transport selected fluids or molecules in a feed flow stream across the surfaces of the porous membranes in the membrane cassettes during operation. Feed slots may transport selected fluids or molecules through the membrane device in a cross-current flow pattern or a counter-current flow pattern. Porous metal membranes provide a selected mass exchange for components within a feed flow stream introduced to the membrane device and a permeate flow stream removed from the membrane device during operation. Porous metal membranes may include or be constructed of various metals and metal alloys. Metals and metal alloys include, but are not limited to, e.g., nickel (Ni) metal, nickel-iron (Ni—Fe) alloys, nickel-copper (Ni—Cu) alloys, stainless steel alloys, titanium (Ti) metal, titanium alloys, including combinations of these various metals and metal alloys.

The membrane module separates or filters particulates or molecules of a selected size from the feed flow streams introduced into the membrane device. The support frame may include depressions positioned on respective faces of the support frame that form feed flow slots and permeate (or sweep) flow slots in each of the membrane cassettes in the membrane device. Feed slots on selected sides of the membrane device are oriented in a direction 90 degrees from permeate (or sweep gas) slots on other sides of the membrane device.

Porous metal membranes may be separated a selected distance apart on the support frame of the membrane cassettes. The membranes provide filtration or separation of particulates from feed streams introduced through the feed slots of the metal cassettes in the membrane device

In some applications, the porous metal membranes may be symmetric membranes. In some applications, the porous metal membranes may be asymmetric membranes. Porous metal membranes may include pores of a size between about 0.010 μm and about 10 μm.

Porous metal membranes may have a selected thickness. Thickness of the membranes may be selected to reduce or minimize transport resistance of the selected molecule or materials across the membranes of the membrane device. Porous metal sheet membranes may have a thickness selected between about 20 μm and about 200 μm.

Membranes in the membrane device allow two process flow streams to remain separated from the other process flow stream while allowing selected molecules or selected materials to cross through the membranes.

Porous metal sheet membranes in the membrane cassettes may include a backing material constructed of one or more layers of a porous or fluid-permeable material or structure placed on the rear or back side of the membranes to support the membranes in the membrane cassettes. Backing materials may include, but are not limited to, e.g., polymers, metals, and combinations of these materials. In some applications, the backing material may include a porous polyester sheet. In some applications, the backing material may include a porous polyester sheet that is conjugated with a metal mesh. Backing materials minimize flow resistance for sweep flow streams to flow through the membrane cassettes between the back surfaces of the two membrane sheets. Flow direction during mass-transfer may be parallel to the membrane surface.

Backing materials may include a thickness selected between about 0.05 mm and about 5.0 mm. Backing materials may include a porosity defined by the ratio of the open area to total area of between about 0.2 and about 0.95.