



Manufacturing & Prototyping

Microfabrication of a High-Throughput Nanochannel Delivery/Filtration System

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A microfabrication process is proposed to produce a nanopore membrane for continuous passive drug release to maintain constant drug concentrations in the patient's blood throughout the delivery period. Based on silicon microfabrication technology, the dimensions of the nanochannel area, as well as microchannel area, can be precisely controlled, thus providing a steady, constant drug release rate within an extended time period. The multilayered nanochannel structures extend the limit of release rate range of a single-layer nanochannel system, and allow a wide range of pre-defined porosity to achieve any arbitrary drug release rate using any preferred nanochannel size. This membrane system could also be applied to molecular filtration or isola-

tion. In this case, the nanochannel length can be reduced to the nanofabrication limit, i.e., 10s of nm.

The nanochannel delivery system membrane is composed of a sandwich of a thin top layer, the horizontal nanochannels, and a thicker bottom wafer. The thin top layer houses an array of microchannels that offers the inlet port for diffusing molecules. It also works as a lid for the nanochannels by providing the channels a top surface. The nanochannels are fabricated by a sacrificial layer technique that obtains smooth surfaces and precisely controlled dimensions. The structure of this nanopore membrane is optimized to yield high mechanical strength and high throughput.

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Improved Design and Fabrication of Hydrated-Salt Pills

Salt pills for adiabatic-demagnetization refrigerators could be mass-produced.

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A high-performance design, and fabrication and growth processes to implement the design, have been devised for encapsulating a hydrated salt in a container that both protects the salt and provides thermal conductance between the salt and the environment surrounding the container. The unitary salt/container structure is known in the art as a salt pill. In the original application of the present design and processes, the salt is, more specifically, a hydrated paramagnetic salt, for use as a refrigerant in a very-low-temperature adiabatic-demagnetization refrigerator (ADR). The design and process can also be applied, with modifications, to other hydrated salts.

Hydrated paramagnetic salts have long been used in ADRs because they have the desired magnetic properties at low temperatures. They also have some properties, disadvantageous for ADRs, that dictate the kind of enclosures in which they must be housed:

- Being hydrated, they lose water if exposed to less than 100-percent relative humidity. Because any dehydration compromises their magnetic properties, salts used in ADRs must be sealed in hermetic containers.
- Because they have relatively poor thermal conductivities in the temperature range of interest (<0.1 K), integral thermal buses are needed as means of efficiently transferring heat to and from the salts during refrigeration cycles. A thermal bus is typically made from a high-thermal-conductivity metal (such as copper or gold), and the salt is configured to make intimate thermal contact with the metal. Commonly in current practice (and in the present design), the thermal bus includes a matrix of wires or rods, and the salt is grown onto this matrix. The density and spacing of the conductors depend on the heat fluxes that must be accommodated during operation.

Because the salt is hydrated, it must be grown from solution onto the matrix, in a container that, immediately after growth, must be hermetically sealed to complete the salt pill. In the present design and fabrication process, the thermal bus is initially fabricated in two pieces: (1) a unitary piece comprising a square array of parallel copper fingers protruding from a copper disk, and (2) a copper cap that can be bolted into thermal contact with an external object. The disk-and-fingers piece is made from a single copper rod by using automated electrical-discharge machining (EDM) to create the gaps between the rods. Prior to EDM, the bolt holes (for subsequent connection to other parts of the ADR) and two access holes (for use in growing the magnetic salt) are machined into the copper rod.

In a single brazing operation, the two copper pieces constituting the thermal bus are joined together, two stainless-steel weldment rings are joined to the