ARTIFICIAL ORGANS

Researchers are working towards fabricating state-of-the-art artificial lungs using gas-permeable materials containing myriads of microchannels.

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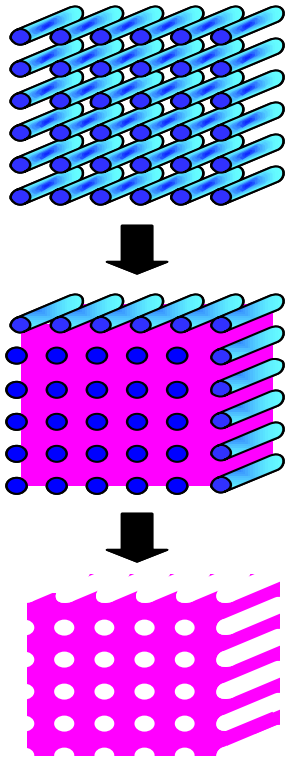
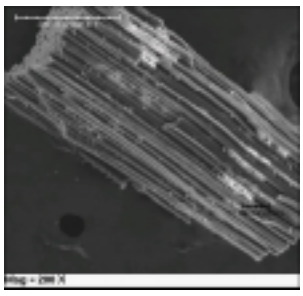
Objective: A major function of most internal organs (*e.g.*, lungs, kidneys, liver, and pancreas) is the transport of chemical species to and from blood. This transport occurs *in vivo* predominately at the capillary level of the circulation, where the width of the blood-side passageway is on the order of 5-10 μm. In contrast, due to technology limitations current devices that attempt to replace or supplement inadequate or failed organ functions have the blood-side passages on the order of 200-400 μm. As a result, these organ-function replacement devices have overall mass transfer coefficients that are relatively poor when compared to their physiological counterparts and are hence less efficient than human organs. Under the direction of H. Kung, L. Mockros, and M. Kung, researchers aim at producing arrays of microchannels with diameters of 10-25 μm, embedded in a gas-permeable matrix material, that are intended to be basic components for the future design of artificial organs, of which lungs are the primary target. Organ function replacements devices that contain such novel components would have much higher chemical exchange rates with the blood stream than those realized in current devices. They would also be much smaller and hence suitable for pediatric and transplant applications.

Approach: Producing the microchannel assemblies will require (a) making bundles of closely spaced fibers, which will serve as templates; (b) imbedding the fibers in a gas-permeable matrix; (c) removing the fibers, thereby creating an assembly of microchannels within the matrix wafer; (d) machining the wafer to the desired shape; (e) coating the external faces with a thin, impermeable film; and (e) if needed for biocompatibility and biostability, coating the microchannel walls and wafer surfaces with a thin layer of biocompatible and biostable material, such as silicone rubber.

Results: The researchers have performed detailed calculations and determined that approximately 100 million microchannels will be needed to satisfy the requirement related to gas phase transport to oxygenate 4 L/min of blood using air at atmospheric pressure. In a series of proof-of-concept experiments, they have fabricated 0.6 millimeter thick wafers containing approximately 5,000 microchannels per mm^2 by polymerizing a mixture of methylmethacrylate, dimethylitaconate and ethylenglycoldimethacrylate around a bundle of commercially available glass fibers and subsequently dissolving the fibers with a sequence of hydrofluoric acid, concentrated amine, and sodium hydroxide. Optical microscopy indicates that the glass fibers are reasonably well distributed, and scanning electron micrographs (SEM) of pieces intentionally broken off from the wafer show formation of straight channels each about 12 μm in diameter with clean walls throughout the wafer. Current efforts are focused on improving the methodology for synthesizing wafers by exploring different materials used for the matrix and the template. Wafers that contain the best physical characteristics such as uniform channel distribution and smooth, clean channel walls will be tested for leakage and gas transfer efficiency. The most promising candidates will be then tested for oxygenation of blood.



The key conceptual steps in fabricating of a matrix wafer: a bundle of uniform-diameter fibers (top) is coated with a polymeric gel (center). After curing the gel, the fibers are removed (bottom) leaving the straight channels in the matrix.



SEM of a piece of matrix containing 12 μm channels.