Biomedical microdevices enabled by microfluidic technology

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Microfluidics is the science and technology of manipulating and analyzing fluid flow at small scales, typically from millimeters down to micrometers. At these scales, fluid flow is almost always laminar which enables excellent control over the flow. Another special feature at these scales is the dominance of surface tension, which provides the possibility to exploit capillary effects to effectively manipulate fluids. Microfluidic devices can be made using a range of microfabrication approaches and materials, and these enable to integrate tailored electronic or mechanical functions.
These unique properties of microfluidic technologies enable a range of new biomedical applications. In this lecture, I will show three microfluidics-technology-enabled biomedical microdevices we are developing in our lab. (1) A cancer-on-chip device in which can create a breast duct and a blood vessel to mimic and study the process of cancer cell invasion, migration, and intravasation. (2) A wearable sweat sensing device that is clamped on the finger of hospitalized patients so that critical biomarkers like lactate, cortisol, and glucose can be continuously monitored. (3) A smart glaucoma eye implant in which a magnetic microvalve is integrated that, after implantation, can be switched using an external magnet to keep the eye pressure within safe limits..

Figures

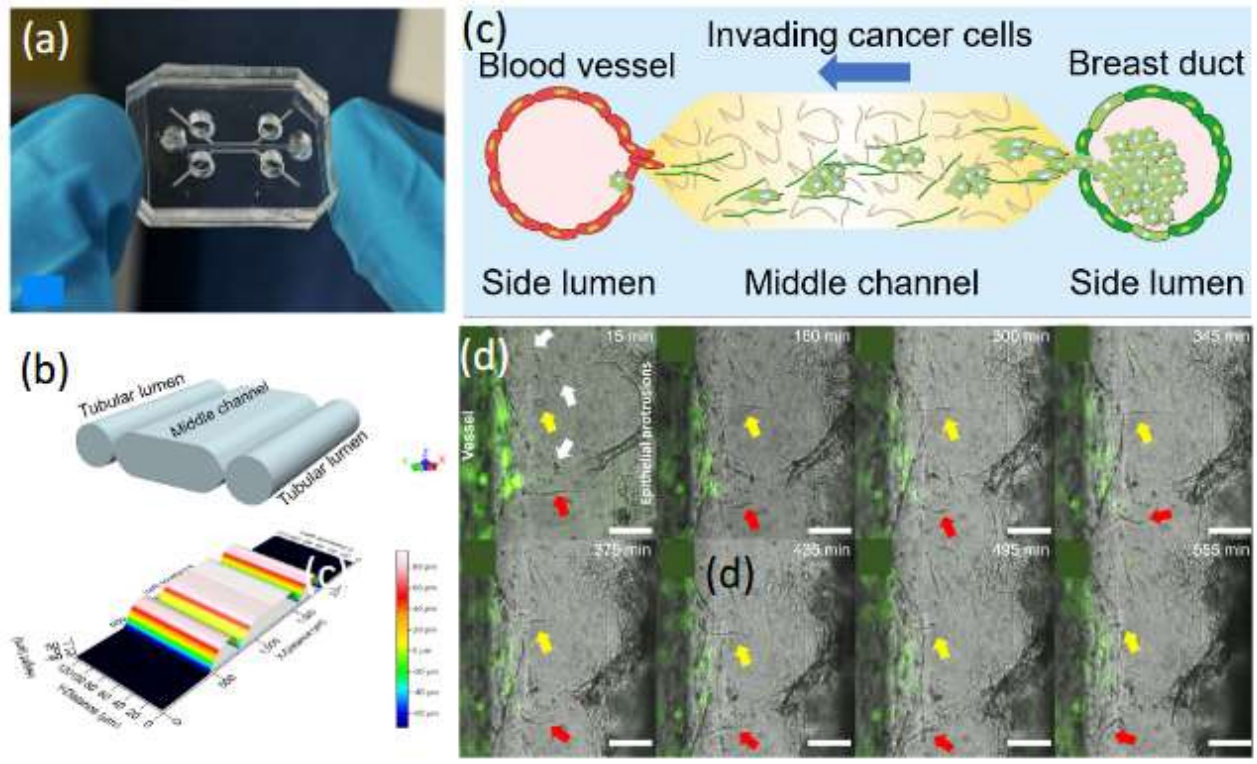

Figure 1. Cancer-on-chip device to study tumor cell invasion, migration, and intravasation. (a) Photo of the device, made in glass using femtosecond laser machining. (b) The channel structure consisting of two lateral tubular channels and a middle compartment; The micro-gaps connecting the lateral tubular channels to the middle compartment are fully open along the main axes of the channels. (c) Schematic representation of the cross section of the chip, depicting cancer cell invasion from a breast duct epithelium into the collagen I
matrix,
and further intravasation into the vessel. (d) Images of cancer cell invasion and intravasation progression at several time frames up to 555 min after 6 days in culture (triculture of MCF10a, MDA-MB-231, and HUVECs). Arrows show the cancer cells in the collagen I between the epithelium (right) and endothelium (left); yellow and red arrows in each point to an individual cancer cell migrating towards and intravasating into the vessel. HUVECs (green). Scale bar, 100 μm.

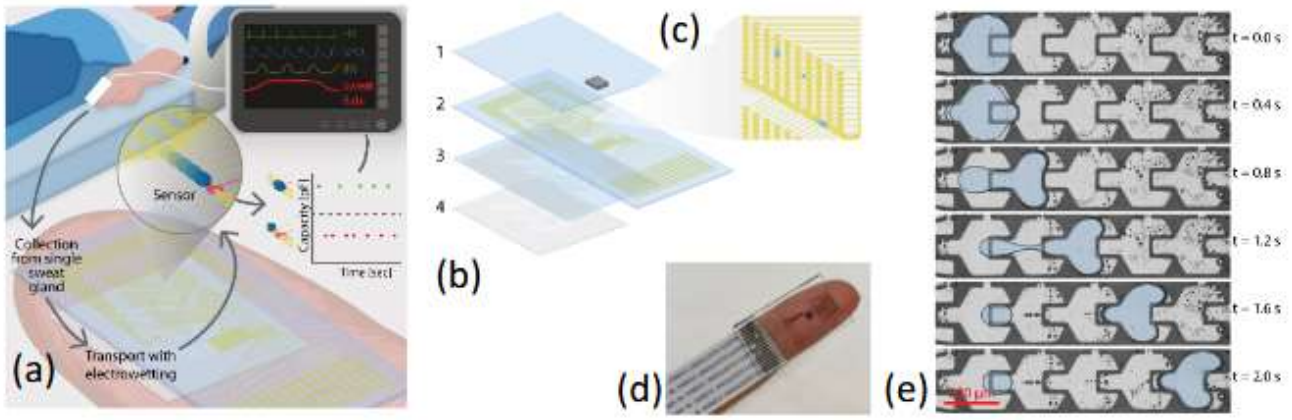

Figure 2. Wearable sweat sensing device**.** (a) The sweat sensor device is clamped on the patient's finger, continuously samples sweat, and determines biomarker content. (b) Exploded view of the device with different device layers: (4) patterned medical tape, (3) glass collection plate, (2) electrowetting layers, (1) biosensor location. (c) Top view of one electrowetting structure section. (d) The actual device on a fingertip. (e) Demonstration of electrowetting transporting sub-nanoliter sweat droplets within the device

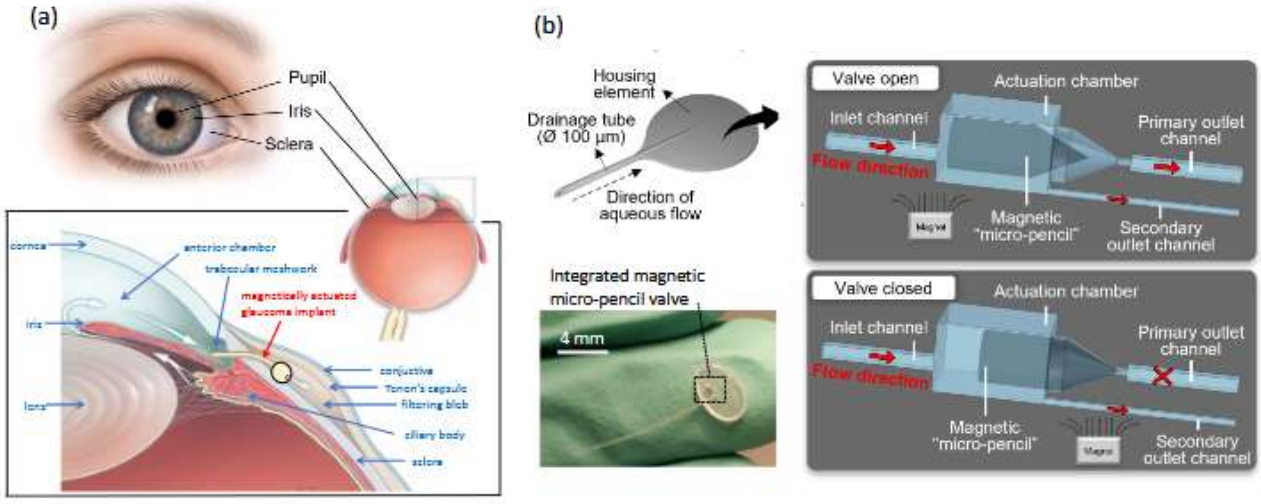

Figure 3. Smart glaucoma drainage device. (a) Anatomy of the eye and placement of the magnetically actuated glaucoma implant in the eye. (b) Schematic depiction of the magnetically adjustable glaucoma implant design, a photo of the actual device, and the actuation mechanism of the integrated micro-pencil valve; the total length and largest diameter of the magnetic micro-pencil are 1 mm and 350 µm.