VCAF as a MEMS material

We introduce a new material to MEMS, namely vertically conductive adhesive foil (3M 9703 Electrically Conductive Adhesive Transfer Tape, 3M, St. Paul, MN, USA). Conductive adhesive foils are commonly used in a range of applications, e.g. in flat-panel displays [1-3]. In our microfluidic sensor, the tape provides characteristics solving a three-fold design challenge. Firstly, the QCM must be integrated with the other device parts without mechanical clamping, since the latter causes uneven stress or strain and lead to frequency drift or increased noise. Secondly, electrical contacting to the electrodes of the encapsulated quartz crystal must be made in the integrated device. Thirdly, buffer liquid must be provided through the fluidic system to the immunoassay at the QCM surface without any leakage. The VCAF is a filled acrylic pressure sensitive adhesive (PSA) that can be applied to several types of materials, e.g. copper, gold, aluminium, steel, epoxy, polyimide, polyester etc[4]. It allows for rapid bonding in room temperature but its adhesion is improved for a dwell time of up to 24 h and with heat treatment of up to 70° C. The ease of handling and the excellent adhesive properties make the tape suitable for integrating MEMS parts into large-scale devices. In our design, the VCAF holds all device parts together. It eliminates the need for mechanical clamping of the QCM and by only bonding a single side of the crystal, issues concerning bending, skewing, or changes in mechanical conditions are avoided. The tape used in this study has a thickness of 50 µm and determines the spacing between the silicon diaphragm and the quartz crystal. The limited thickness makes it possible to rely on diffusion as the dominant transport mechanism in this application.

Apart from the adhesive properties of the VCAF, it also offers anisotropic electrical conductivity. Conductive beads are distributed in the PSA matrix which makes vertical electrical connection possible through the thickness of the foil, but due to the intermediate in-plane spacing between each particle the tape is insulating in the plane of the foil. During assembly, an applied pressure establishes a good electrical contact between the beads and the substrate materials. The contact resistance of $1.9 \cdot 10^{-4}\ \Omega/\mathrm{cm}^2$ can be compared to the insulation resistance of $5.3 \cdot 10^{13}\ \Omega/\mathrm{cm}^2$ [4]. In our device, this allows for electrical contacting between the gold pads on the silicon chip and the electrodes on the quartz crystal as well as the external electrodes without risking any short circuits.

A third feature of the tape that is taken to advantage in this device is its sealing properties to liquids. The adhesive together with the microchannels in the silicon chip define and seal the liquid compartments of the device. When using aqueous solutions, the bond between the

VCAF and other materials is sustained but when applying solvents, such as propanol, the tape is dissolved and the parts can be easily dismounted.

In conclusions, the VCAF seals the fluidic system, allows for electrical contacting between the contacts pads on the silicon and on the quartz crystal but prevents shortcuts to the rest of the system, and by allowing for single-sided bonding of the crystal to the silicon it eliminates the need for mechanical clamping. In addition to the above features, the thin tape also keeps the diffusion length, i.e. the spacing between the diaphragm and the QCM, within an acceptable range.

VCAF material performance

Blister testing[5] of 3M 9703 VCAF was carried out to evaluate the usability of the material for MEMS and microfluidics applications. Circular 5 mm diameter disks of VCAF were punched out and mounted on cleaned polycarbonate, monocrystalline silicon (100 p-type), PMMA, glass (AF 45 microscope glass slide), Au (400 nm evaporated on microscope glass slides), and PDMS (Sylgard 184, Dow Corning, Midland, MI, USA) substrates. Each substrate was provided with a 1 mm diameter hs-drilled through hole and cleaned in the following procedure: 15 min IPA, 5+5+5 min DI, 45 min 115 °C dehydration. The tape pieces were aligned to cover the pressure supply hole and fixated using a 50 kPa clamping pressure. During the tests, the VCAF blister was pressurized through the pressure supply hole by increasing an applied hydrostatic pressure, see figure 1 for an illustration of the setup. The pressure was monitored with dual pressure gauges (analogue and electronic; MPX5100DP, Freescale Semiconductor, USA) and the result was recorded with a computer coupled to the pressure sensor and a digital video camera that measured the scattering of a laterally incoming laser beam that was pointed towards the blister and aligned just above the VCAF.

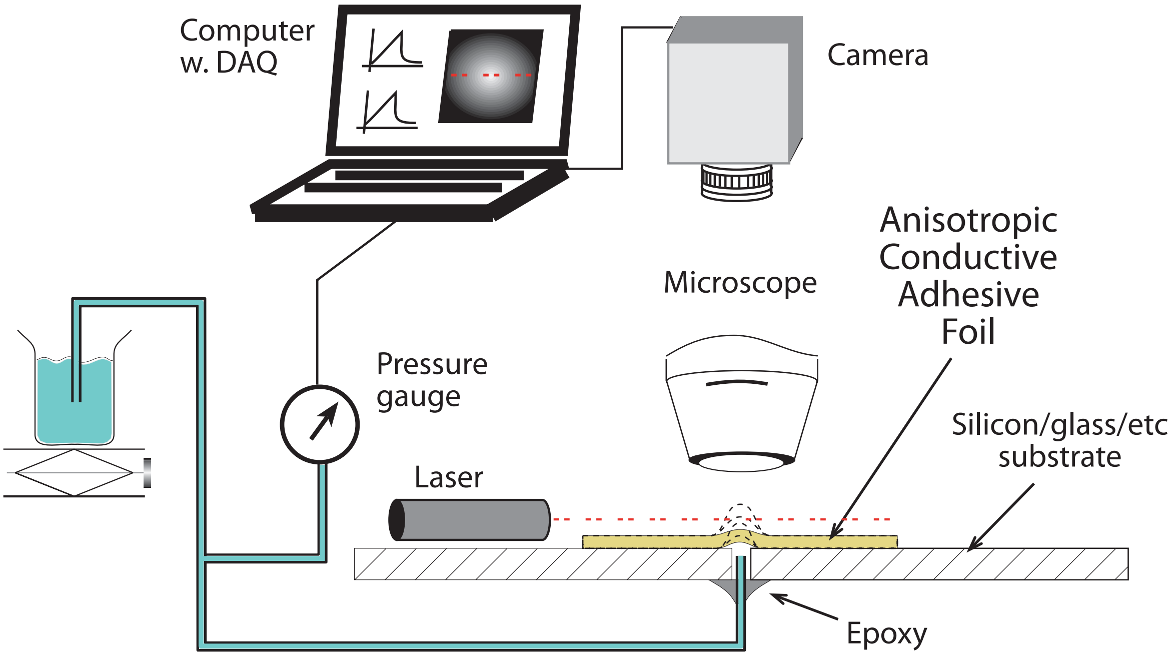

Figure 1. *Schematic illustration of the measurement setup. DI water was used for hydrostatic pressure generation. With the laser beam aligned just above the adhesive foil, small changes in the blister size were possible to record with the microscope camera by scattering of the incoming light.*

The results from the blister tests are shown in figure 2. Standard polycarbonate withstood pressures ranging from 12-16 kPa, silicon 15-39 kPa, PMMA 22-43 kPa, glass 24-28 kPa, Au 30-42 kPa, and PDMS 36-55 kPa. The VCAF blisters burst most commonly where a conductive bead was embedded.

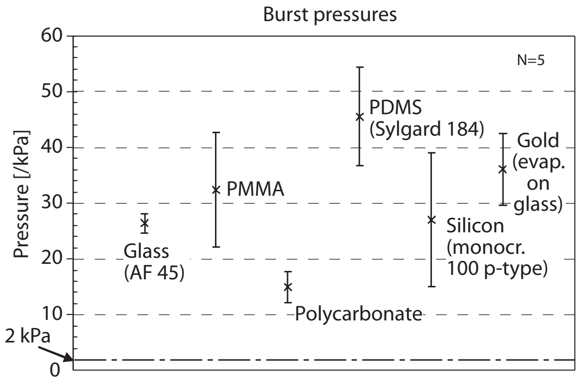

Figure 2. *Blister tests done with VCAF on a six relevant microfabrication materials. The dash-dotted line indicate the pressure used in our microfluidic system (approximately 1-2 kPa).*

References

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