# Diamond Probes for Nanotechnology

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Micromachined CVD diamond tips are robust tools of great interest for scanning probe microscopy and nanoscale materials testing. When doped with boron, they are electrically conducting and can be used as electronic probes. Two applications that are relevant for semiconductor fabrication are described here.

In scanning spreading resistance measurements (SSRM), the local contact resistance is measured, in order to determine the local carrier concentration (Fig. 1). Relatively large pressures have to be applied so as to penetrate the native oxide layer and to generate a metallic region underneath the contact. This poses high demands on the probe, namely high sharpness, low wear, high conductivity, stiff cantilevers and high resistance against lateral forces. In collaboration with IMEC, molded pyramidal diamond tips integrated in silicon cantilevers have been developed [1].

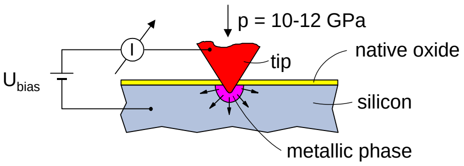

Figure 1
Scanning spreading resistance measurements

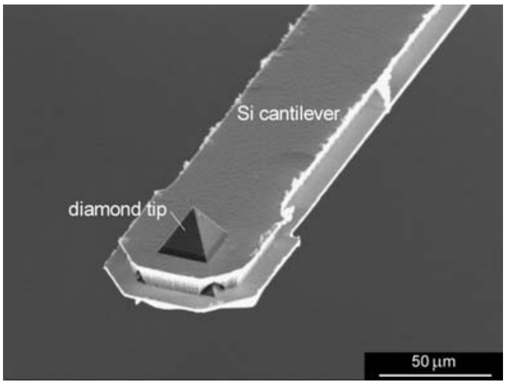

Figure 2
Pyramidal diamond tip in silicon cantilever

These cantilevers have been successfully tested for SSRM, showing a significantly higher dynamic range for the doping concentration measurement than the conductive probes known to date.

Another application concerns the measurement of the dielectric strength of the gate oxides in CMOS technologies. The quality of gate oxides is of increasing importance since they are becoming thinner along with the reduction of the lateral dimensions of integrated circuits. When using a local oxidation process (LOCOS), a particularly critical region is the border between the gate oxide and the field oxide where the oxide is thinner (see inset in Fig. 4). As this area cannot be reached with pyramidal AFM diamond tips, high aspect ratio diamond tips have been developed and successfully tested, in collaboration with Infineon [2].

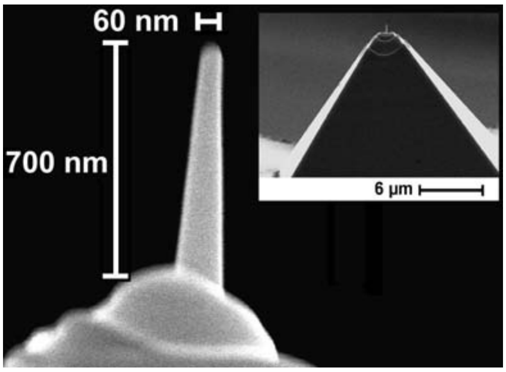

Figure 3
FIB sharpened pyramidal diamond tip

Pyramidal diamond tips have been modified by focused ion beam (FIB) etching. This resulted in high aspect ratio (limited only by the wall thickness of the pyramids), conducting, pure diamond tips of 30 nm apex radius, as shown in Figure 3. The tips proved to be very robust and capable of characterizing a gate oxide of model devices by simultaneous recording of topography and Fowler-Nordheim (FN) current at the relatively high bias of 18.7 volts (Fig. 4). The brightened line in the conductivity image shows a thinned area of gate oxide along the field oxide (FN current).

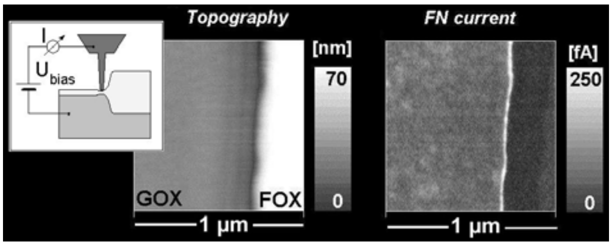

Figure 4
Simultaneously measured topography and FN current images in the boundary region between a 20 nm thick MOS gate oxide (GOX) and a much thicker field oxide (FOX)

These two particularly demanding applications demonstrate the versatility of diamond probes for electronic surface characterization.

The project partners are the Interuniversity Microelectronics Centre (IMEC) in Leuven, BE and Infineon AG, Munich, DE.

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[1] T. Hantschel, Ph. Niedermann, T. Trenkler, W. Vandervorst, "Highly conductive diamond probes for scanning spreading resistance microscopy", Appl. Phys. Lett., accepted for publication

[2] A. Olbrich, B. Ebersberger, C. Boit, Ph. Niedermann, W. Hänni, J. Vancea, H. Hoffmann, "High aspect ratio all diamond tips formed by focused ion beam for conducting atomic force microscopy", J.Vac.Sci.Technol. B 17 (1999) 1570