

Nanoimprinted metallic probe demonstrators for electrical scanning probe microscopy: Manufacturing, characterization, and application

J. D. Jambrech^a, V. Yanev^a, H. Schmitt^a, M. Rommel^a, A. J. Bauer^a, L. Frey^{a,b}

^a Fraunhofer Institute for Integrated Systems and Device Technology (IISB), Schottkystrasse 10, 91058 Erlangen, Germany

^b Chair of Electron Devices (LEB), Friedrich-Alexander-University Erlangen-Nuremberg, Cauerstrasse 6, 91058 Erlangen, Germany

Motivation

Decreasing feature sizes in semiconductor technology will require electrical characterization techniques with nanometer resolution. Promising methods based on SPM (scanning probe microscopy) are widely used:

- SCM (scanning capacitance microscopy)
- TUNA (tunneling AFM) and/or CAFM (conductive AFM)
- SSRM (scanning spreading resistance microscopy)

Currently, for these methods silicon tips coated with a conductive material are used, which has certain disadvantages.

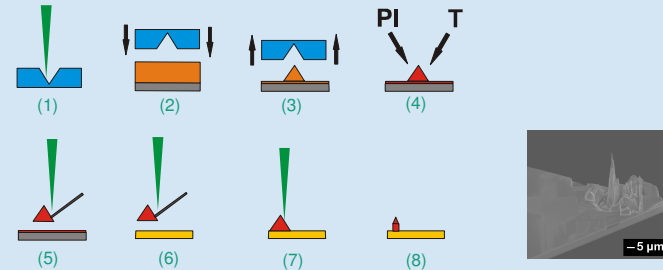
- **Metal coated tips:** Highly conductive **metal layer wears out** during use
- **Diamond coated tips (doped diamond layer):** Wear resistant but relatively **low conductivity** and **lower spatial resolution**

New solution: **Metallic tips** on conductive cantilevers manufactured using UV nanoimprint lithography and focused ion beam processing offer multiple advantages:

- Relatively **low** and most of all **constant resistivity** even after considerable **wear**
- Better **conductivity** than diamond coated tips
- Can be manufactured with **optimized shapes** also in the initial stage

Demonstrators of metallic probes were manufactured, electrically characterized, and evaluated.

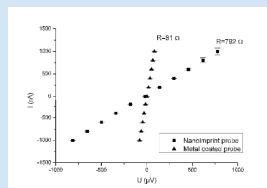
Preparation of nanoimprinted metallic probes



- (1) FIB (focused ion beam) processing is used to generate a template for UV-NIL (UV nanoimprint lithography)
- (2) Tip is imprinted by UV-NIL on a silicon wafer ...
- (3) ... using a resist which is a mixture of Ag particles and an UV curing polymer
- (4) After imprinting, the tip is treated in an oxygen plasma to remove the UV-polymer and it is thermally annealed to enhance its electrical conductivity
- (5) Tip is connected to a micro-manipulator and removed from wafer by FIB processing
- (6) Tip is attached to cantilever and separated from micro-manipulator
- (7) FIB-milling is used to generate high aspect-ratio and small tip radius
- (8) Demonstrator is ready to be used for electrical SPM measurements

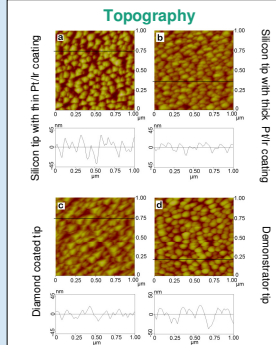
Characterization of probes

The resistances of commercial probes and demonstrator probes were determined by measurements of I-V-curves in contact with a platinum layer.



Metal coated probe 81 Ω
 Demonstrator probe 792 Ω
 Diamond coated probe 18 kΩ

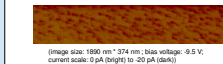
Application of probes



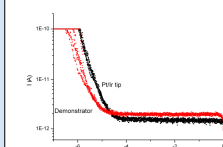
- Demonstrator tips show higher resolution than diamond coated tips and than silicon tips with a thicker Pt/Ir coating but lower resolution than silicon tips with a thin Pt/Ir coating

TUNA

TUNA current map of 4 nm SiO₂-layer on Si using demonstrator probe

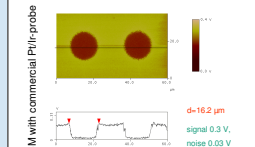
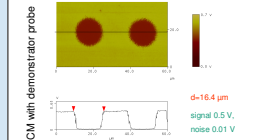


Local TUNA I-V-curves of 4 nm SiO₂-layer



- Demonstrator probes are applicable for TUNA mapping and measurements of local I-V-characteristics

SCM



- Same characteristic features for both measurements
- Higher signal-to-noise ratios for measurements with demonstrator probes

Summary and conclusions

Demonstrators of nanoimprinted metallic probes for electrical SPM were

- manufactured,
- characterized, and
- applied for SPM measurements.

The demonstrators illustrate that probes, consisting of tips manufactured in a batch process by UV-NIL in conjunction with cantilevers, have the potential to show relatively low and most of all constant resistivity in electrical measurements compared to commercially available standard probes.