

Manufacturing, characterization, and application of nanoimprinted metallic probe demonstrators for electrical scanning probe microscopy

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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.

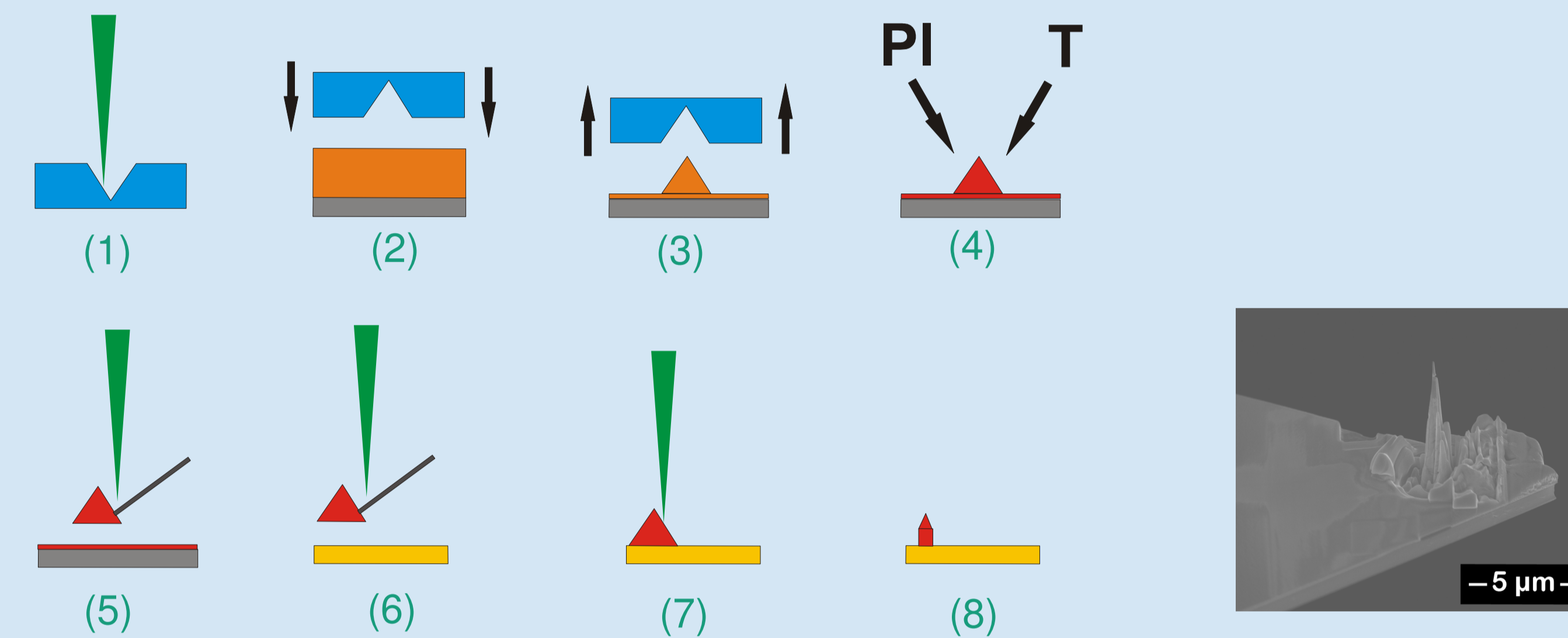
- **Metal coated tips:** Highly conductive **metal layer wears out** during use
- **Diamond coated tips (doped diamond layer):** Wear resistant but relatively **low conductivity** and **lower spatial resolution**

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.

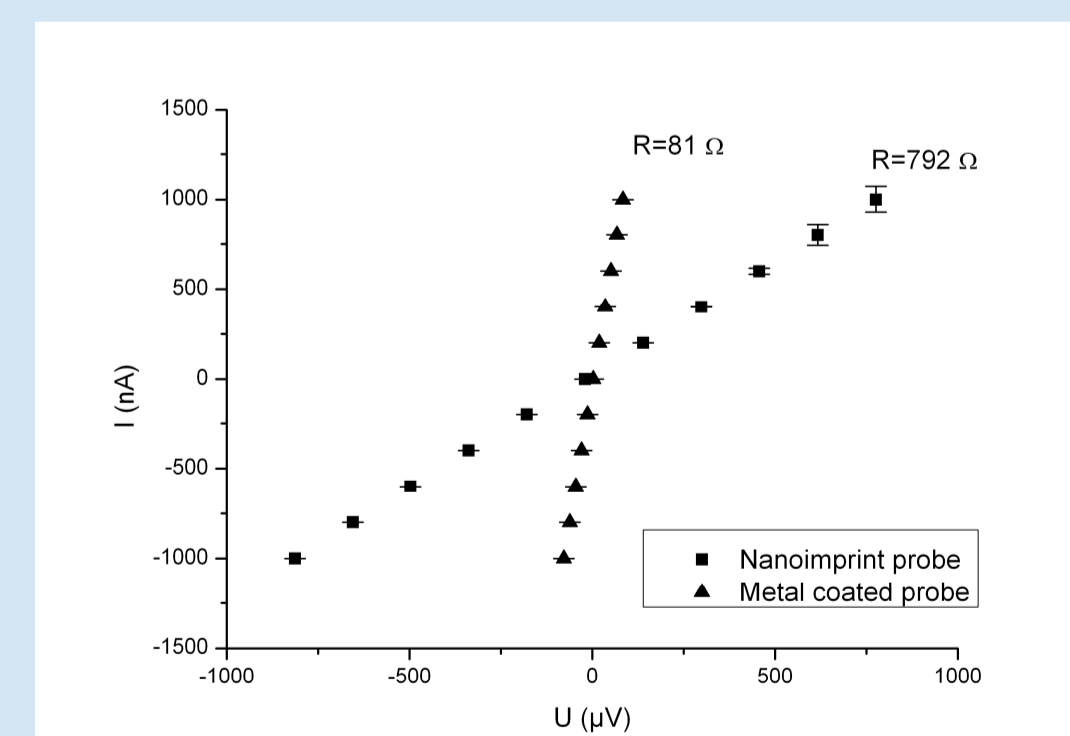
Preparation of nanoimprinted metallic probes



- (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

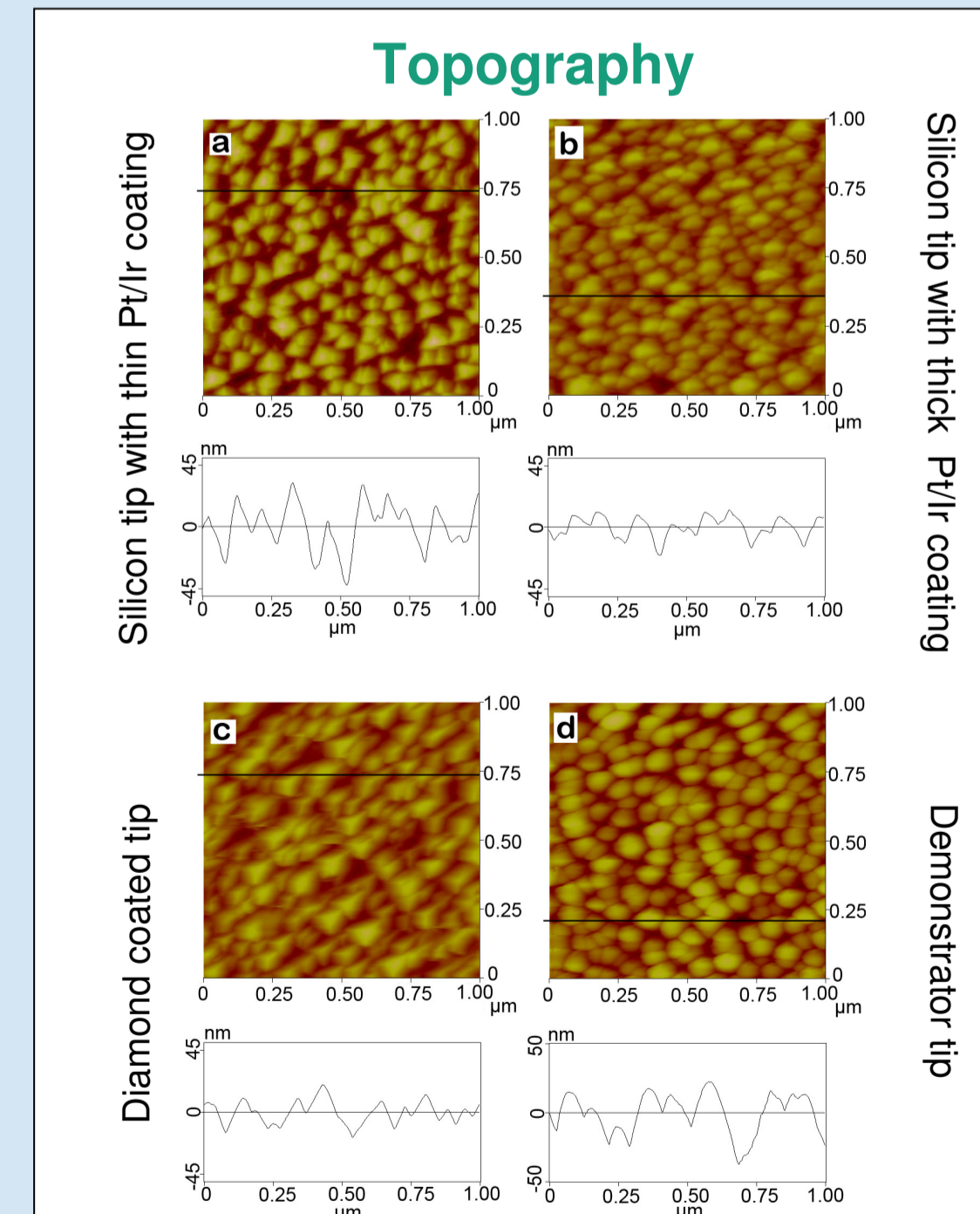
Characterization of probes

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

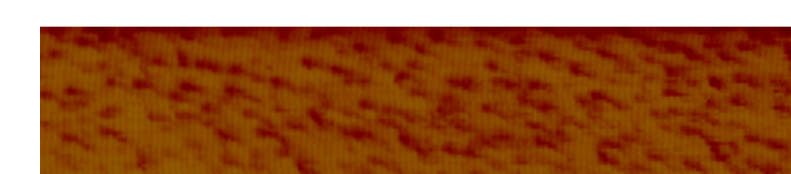
Application of probes



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

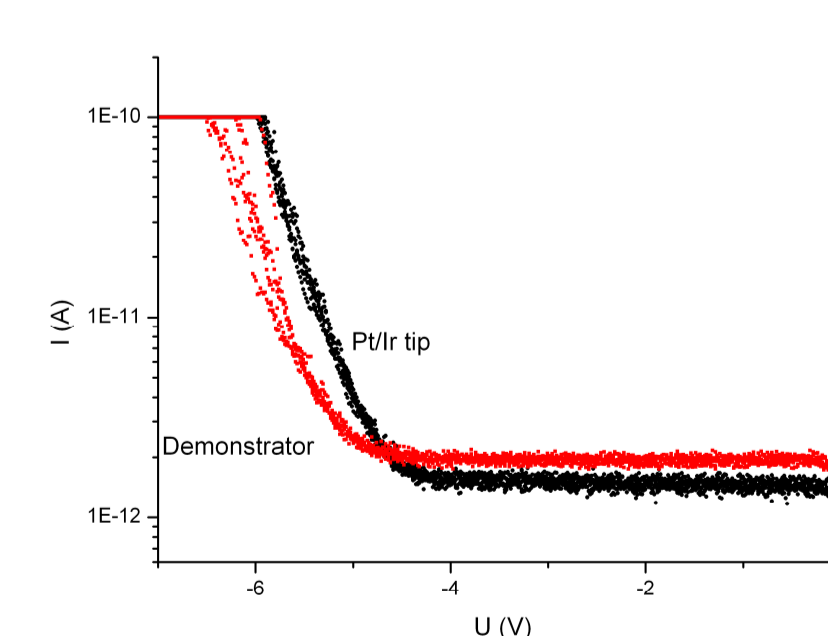
TUNA

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



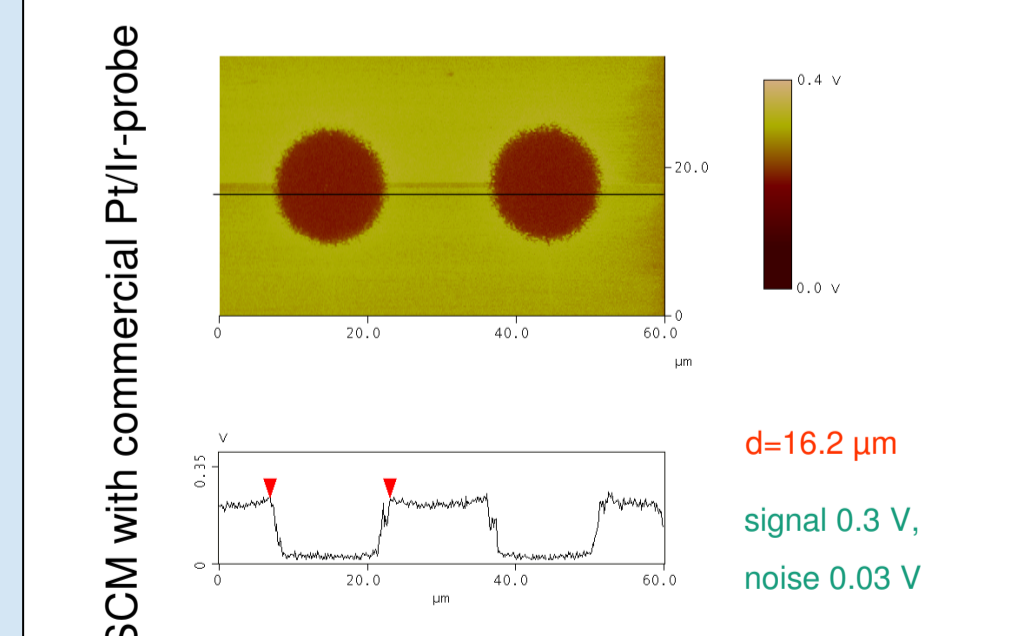
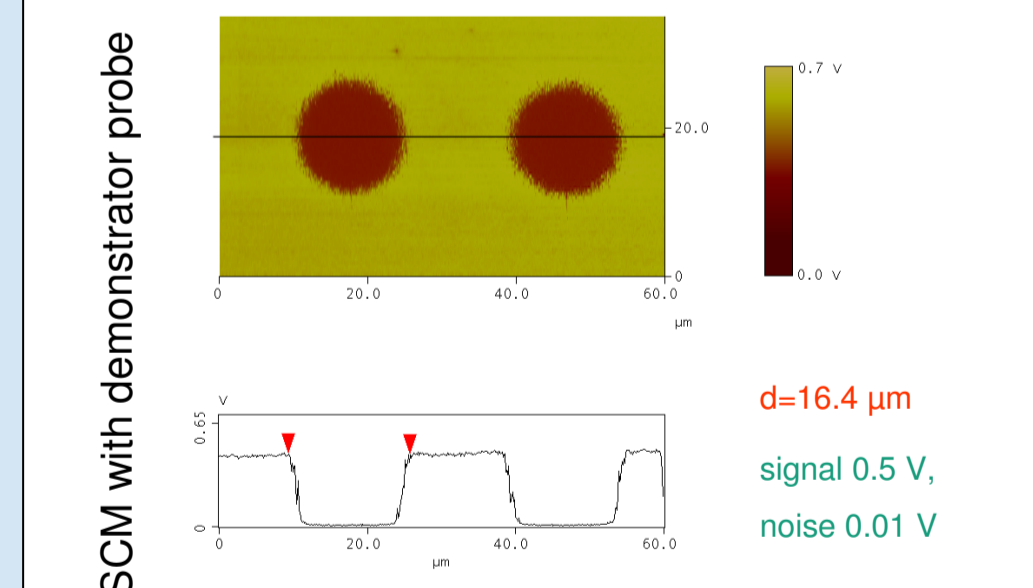
(image size: 1890 nm × 374 nm; bias voltage: -9.5 V; current scale: 0 pA (bright) to -20 pA (dark))

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.