INATECH
INSTITUT FÜR NACHHALTIGE TECHNISCHE SYSTEME

gefördert durch: Carl Zeiss Stiftung

Fraunhofer

UNI FREIBURG

Diamond Tips for Quantum Magnetometry

Björn Christian, Department of Sustainable Systems Engineering (INATECH), University of Freiburg, Germany
Arne Götze, University of Freiburg, Germany
Oliver Ambacher, University of Freiburg, Germany

MOTIVATION AND TARGET

A scanning probe quantum magnetometer can measure magnetic fields with the highest spatial resolution at room temperature. In the process, individual atomic defect complexes in diamond crystals are used to realize the smallest possible magnets. The central element is a nitrogen vacancy center ("NV center") in diamond.

As part of SCHARF we process the nanoscale tip of a diamond measuring head. The tip is then fixed to a cantilever of an atomic force microscope (AFM). By using the AFM the diamond tip with the NV center can be moved across a substrate only nanometers away from its surface. Thus, local magnetic fields can be imaged with very high spatial resolution. This makes it possible to visualize the current distribution in nanoelectronic circuits, since every little electric current generates a magnetic field that is made visible with the aid of quantum magnetometers.

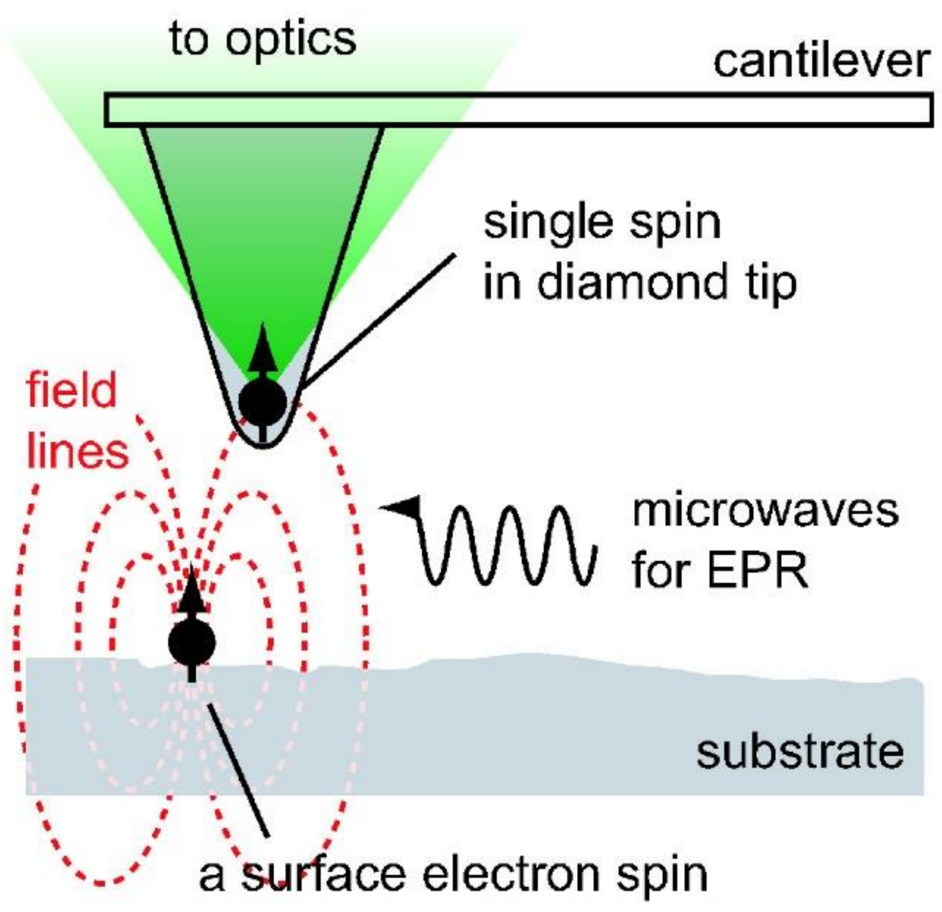

Figure 1: Principle and elements of the scanning probe quantum magnetometer [1]. Microwaves enable electron paramagnetic resonance (EPR). Light emitted by NV-Center is used for magnetometry.

NANO SCALE: NITROGEN VACANCY CENTERS

An NV center is formed when two neighboring carbon atoms are removed in diamond and one is replaced by a nitrogen atom, which causes the excess electron of the nitrogen atom to fall into the vacant space. This electron has a magnetic moment, which can be used after its orientation as a tactile magnet for the field profile to be detected.

The nitrogen atoms are provided by (delta) doping during the growth. The carbon vacancies are generated by He or electron implantation followed by an annealing at high temperatures to form the NV center.

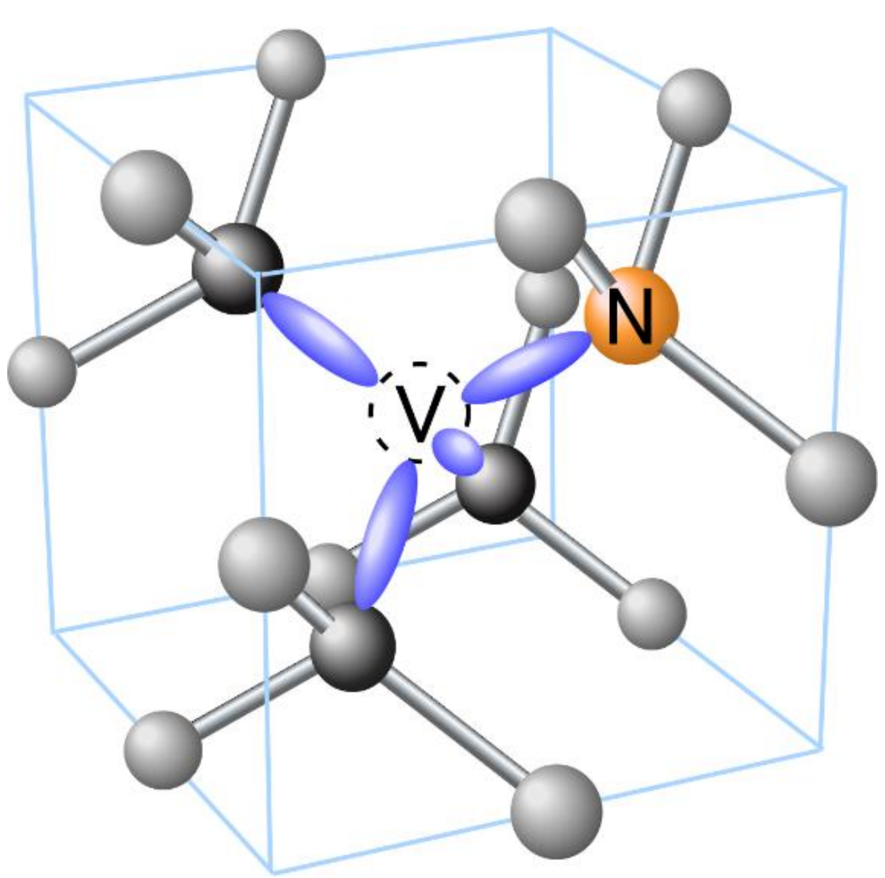

Figure 2: Schematic image of the diamond crystal cubic unit cell with the NV center [2].

MICRO SCALE: DIAMOND TIP

By using a combination of microfabrication processes and chemical vapor deposition (CVD) of diamond we can produce diamond tips that can be integrated into a scanning probe microscope (SPM) in order to realize a quantum magnetometer. By using the SPM to scan the NV center and the magnetic moment of the electron localized within, we can perform very sensitive measurements of magnetic field profiles with a spatial resolution down to 20 nm.

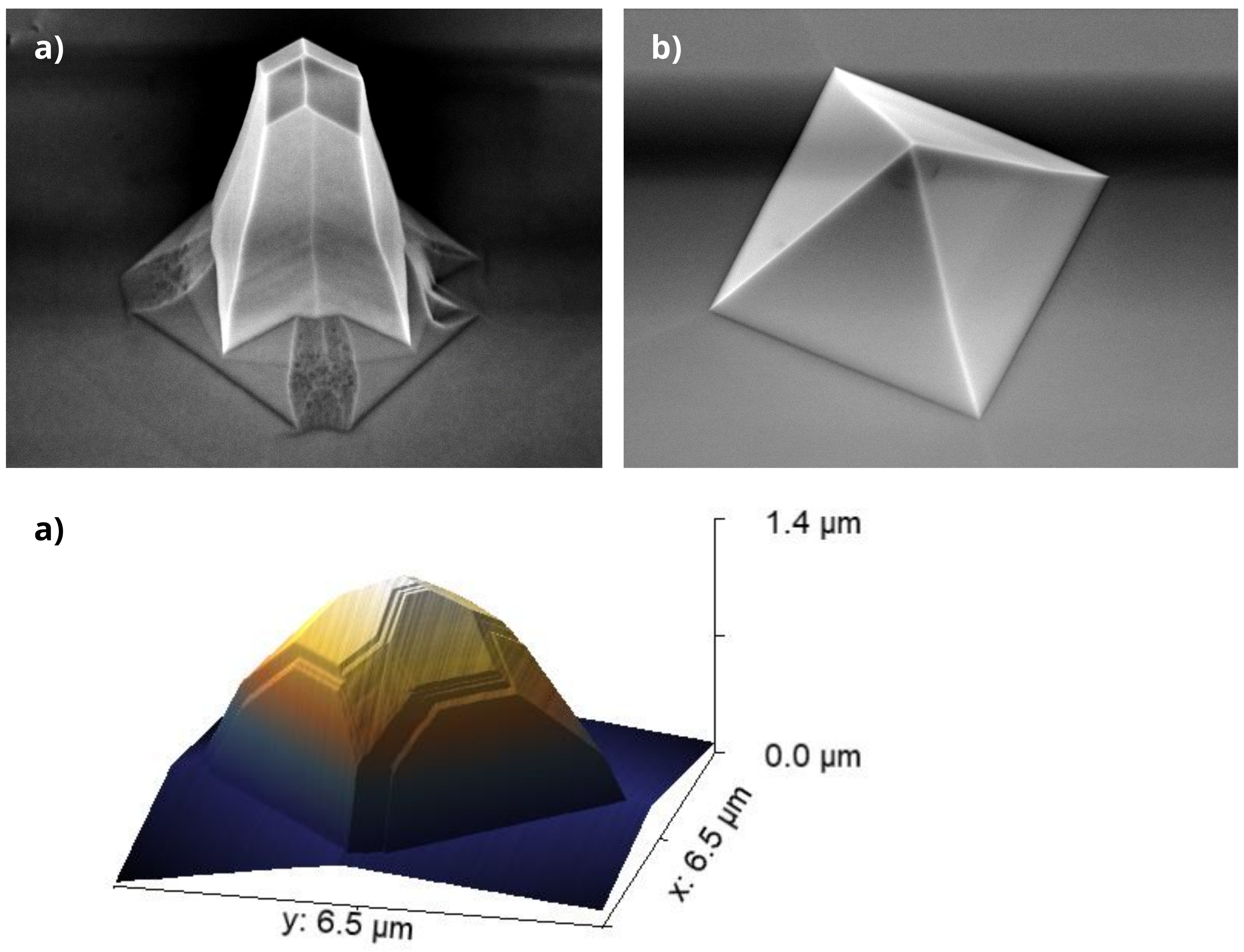

Figure 3: a)/b) scanning electron microscope images of CVD grown diamond tips. c) 3D model of diamond tips as measured by AFM.

MESO SCALE: POLISHING OF DIAMOND SURFACES

Diamond is the hardest known material. Despite this fact we are able to polish it and achieve root mean square (rms) surface roughnesses of R_q < 1 nm. This enables us to perform diamond epitaxy by chemical vapor deposition (CVD) with precise layer thicknesses and doping profiles needed to prepare diamond tips for quantum magnetometry.

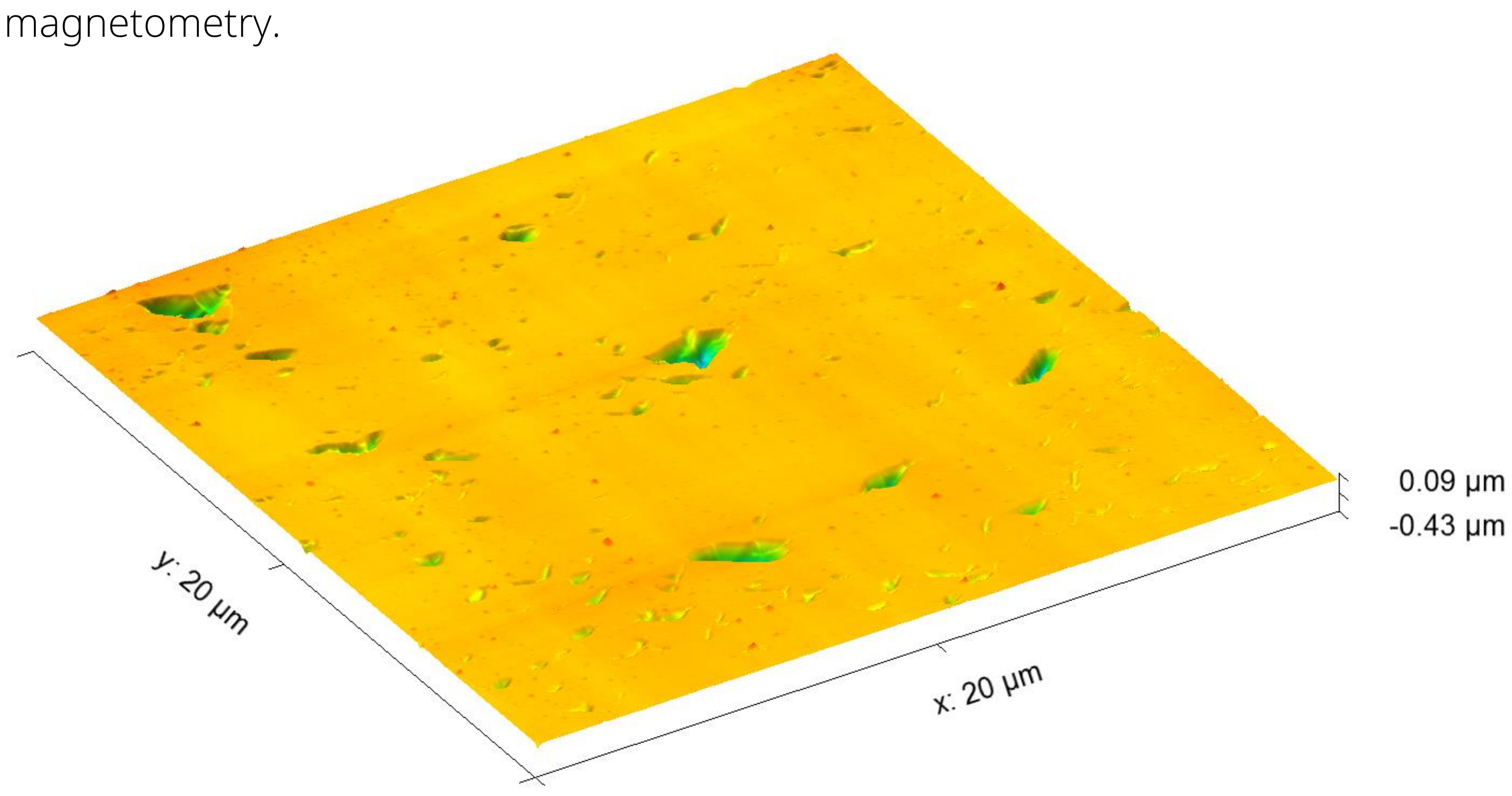

Figure 5: Surface morphology of a polished diamond surface as measured by AFM.

REFERENCES

[1] C. L. Degen; Scanning magnetic field microscope with a diamond single-spin sensor; *Appl. Phys. Lett.* **92,** 243111 (2008)

[2] mizuochilab.kuicr.kyoto-u.ac.jp/research.html#Fig1