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Breaking the limits of functional Atomic Force Microscopy imaging using Focused Electron Beam Induced Deposition

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Atomic Force Microscopy (AFM) has evolved into an indispensable characterization method as it provides quantitative 3D surface information with spatial nanometer resolution. It also enables access to electric, magnetic, optical and thermal properties using specialized functional AFM tips. However, achieving this functionality necessitates additional coating on AFM tips, resulting in increased tip apex size and thus limiting resolution. Moreover, coating introduces the risk of delamination, which could compromise or entirely diminish the functionality of the tip. The aim of our research is to surpass the limitations of functional image quality. To be more precise, it was of interest to achieve (1) higher resolution for functional AFM tips, (2) higher sensitivity for e.g. EFM/MFM phase signal, (3) good signal to noise ratio, and (4) higher wear resistance, compared to commercially available tips.

We have utilized the additive direct-write technology Focused Electron Beam Induced Deposition (FEBID), which enables fabrication of all-functional nano-probes that do not require additional coating. Depending on the application, different requirements become relevant such as tip design, type of precursor (elemental composition), spring constants, and so on. The 3D nano-printing process [1] and a variety of advanced, FEBID-based tip concepts for CAFM, EFM [2], and MFM [3] will be briefly discussed.

Ideal fabrication parameters were individually identified with subsequent determination of post-processing steps based on the required precursor, if needed. The FEBIP tips were then compared with commercially available products in terms of image quality, including resolution, signal-to-noise ratio, wear resistance, among others. After thorough testing of magnetic (M) and conductive tips (C), we give an outlook on further expanding AFM tip capabilities by combining both functionalities, produced with a single precursor. While in the past, MFM and CAFM measurements are operated via different modes, the here introduced MC fusion-probes contain unique possibilities, as both techniques can be performed in a single AFM-CAFM-

MFM experiment. We present first results, which form the basis of this new type of nanoprobes.

FEBID presents an ideal technique for pushing boundaries in functional AFM measurements. All probes share the coating-free character, thereby mitigating the delamination risks during operation. Furthermore, tip apexes are consistently within the sub-10 nm range, enabling high-resolution imaging beyond alternative products.

Graphic:

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Keywords:

FEBID, AFM, EFM, CAFM, MFM

Reference:

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