

## FAST AFM-IMAGING OF BIOLOGICAL SPECIMEN

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**INTRODUCTION:** Imaging and characterization of biological material requires imaging methods that provide a spatial resolution beyond the diffraction limit of light microscopy. The atomic force microscope (AFM) is a well-established tool for imaging as well as for tribological characterization of surfaces with nanometer resolution<sup>1</sup>.

In order to investigate friction on the nanometer scale at technical relevant velocities as well as to monitor biological processes in real-time the operation speed of the AFM has to be improved significantly. We present a method to increase the imaging speed of an AFM by one order of magnitude by utilizing modern model-based control methods.

**METHODS:** The imaging speed of the AFM is limited by the dynamic behavior of the scanning system<sup>2</sup> and the bandwidth of the proportional integral (PI) controller in the vertical direction<sup>3</sup>. To suppress the lateral dynamics of the scanning system an open-loop controller based on the model of the X- and Y-directions is designed<sup>2</sup>. To improve the system performance in the vertical direction a model-based two-degrees-of-freedom controller is implemented<sup>3</sup>.

As test specimen an aluminum structure on a glass surface was used for friction measurement. The sample was made hydrophobic by exposure to the vapor of octadecyltrichlorosilane (OTS).

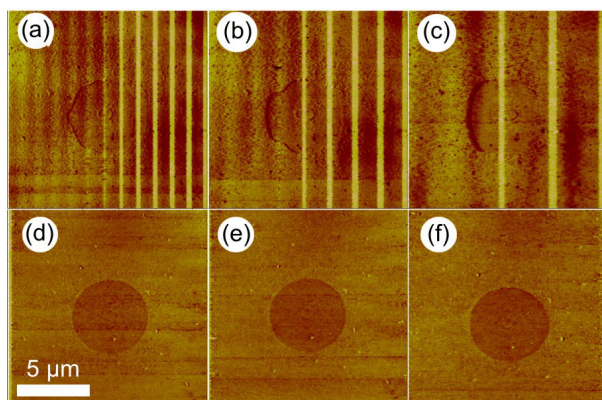


Fig. 1: Lateral force images on aluminum test pattern on glass. (a-c): without compensation, (d-f) with compensation. Scan velocity: (a,d) 1.1 mm/s, (b,e) 1.7 mm/s, (c,f) 3.3 mm/s.

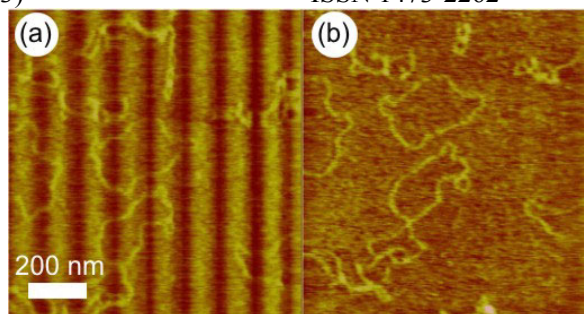


Fig. 2: Topography of pUC-18 plasmid DNA imaged at 61Hz line-scan rate. (a) Standard PI controlled system and (b) model-based controlled AFM. Images are recorded from right to left. Height scale: 3 nm.

Topographic measurements were carried out on pUC-18 plasmid DNA immobilized on muscovite mica.

**RESULTS:** To demonstrate the performance of the AFM with the new controller as compared to the uncompensated system a test specimen was imaged in lateral force mode (Fig. 1). The images in the upper row are dominated by vertical stripes that are induced by the lateral vibrations of the scanner. The images in the lower row show the performance of the compensated AFM system<sup>2</sup>. There is a clear image contrast and the scanner artifacts are absent even at technically relevant velocities. Scanning with the standard AFM system similar imaging artifacts can be observed in the topographic images of plasmid DNA (Fig. 2). The shape of the specimen is distorted and the sample surface shows an apparent corrugation (Fig. 2a). In case of the model-based controlled AFM the imaging artifacts vanish (Fig. 2b).

Concluding, the new controller allows us to perform fast AFM imaging together with reliable friction force measurements at mm/s speed.

**REFERENCES:** <sup>1</sup>Colton et al. (1998) *Procedures in Scanning Probe Microscopies*, Wiley. <sup>2</sup>G. Schitter and A. Stemmer, IEEE Trans. Contr. Syst. Technol., in press. <sup>3</sup>G. Schitter, A. Stemmer, F. Allgöwer (2003) Proc. of the 2003 American Control Conference, Denver, CO, pp. 3720-5.

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