Development of an AFM-in-SEM Nanomanipulation Cell

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Abstract

The controlled manipulation of nano-sized objects is a key technology for the prototyping and integration of NEMS and nanoelectronic devices [1]. A novel setup is presented that combines the capabilities of an AFM with the visual feedback provided by an SEM. The implementation of a teleoperation-mode is described and initial experiments on the manipulation of nano-sized polymer beads are presented.

1 Introduction

The AFM provides a versatile tool for nanomanipulation and nanoassembly [1]. The AFM's force feedback and force control are essential to prevent the manipulated objects from harm and destruction [2]. Although the AFM has repeatedly demonstrated to be a suitable tool to perform nanomanipulation and -assembly [3], the AFM technology as such suffers from various limitations in speed and process control that limits its productive use as a nanoassembly tool. We present a nanorobotic setup that is capable of standard AFM performance and is integrated into an SEM. It offers fast visual feedback provided by the SEM for teleoperated or automated AFM-driven nanoassembly.

2 Hardware Setup

The AFM nanomanipulation system consists of a fine positioning unit with scanning capabilities and a coarse positioning unit. Both are fixed to a common base plate. The left side of Fig. 1 shows the setup mounted onto the stage of the Zeiss Leo 1450 SEM. The piezo-driven fine positioning unit is comprised of a PI-Hera scanner manufactured by Physikinstrumente GmbH (PI) and is equipped with capacitive position sensors. It provides a lateral scanning range of up to 100 µm and a vertical stroke of 50 µm. The integrated capacitive position sensors facilitate a closed-loop

AFM operation that automatically compensates for piezo drift and creep. Nanoscale positioning accuracy and repeatability for the tasks of nanomanipulation and nanorobotic control is also enabled by this integrated position sensor feedback.

The coarse positioning unit uses linear positioners by SmarAct GmbH. These positioners are equipped with optical positioning sensors allowing for travel ranges of several centimeters with a repositioning accuracy of less than 50 nm. The coarse positioning unit carries the samples and enables the user to select any area on a sample for inspection and to select different samples.

Since the setup is mounted on a standard SEM stage, it can be tilted and allows for monitoring the AFM cantilever from normal incidence up to a grazing incidence of 10° with respect to the sample surface. The latter permits observing the interaction between AFM tip and sample by the SEM.

The right part of Fig. 1 shows the surface of a cleaved compact disk (CD) imaged by the SEM and the corresponding image of a smaller central area scanned by the AFM.

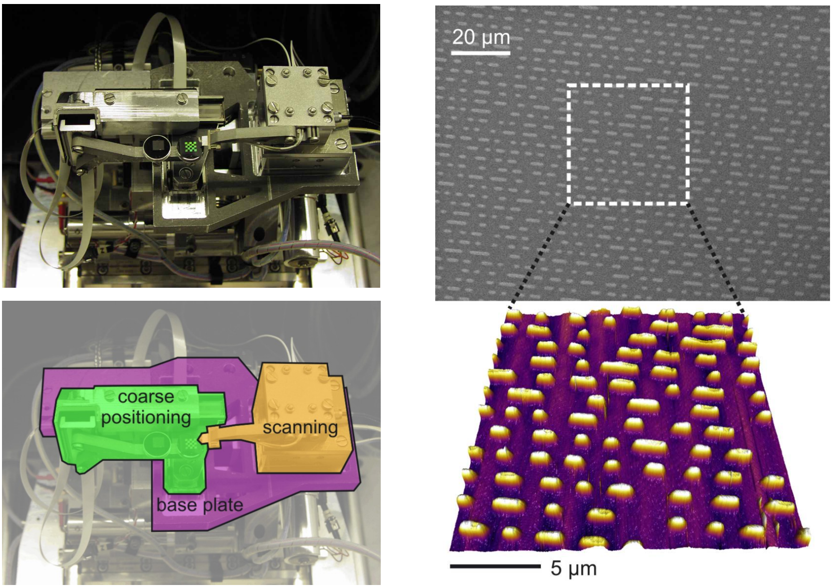

Figure 1: Hardware setup of the AFM-in-SEM nanomanipulation cell (left) and the surface of a compact disk (right) imaged by SEM and AFM, respectively.

3 Framework for Teleoperation

The Division Microrobotics and Control Engineering develops and employs a modular automation framework [4]. The framework consists of three main components, a high-level controller (HiLeC) for scripted automation, a vision control component OlVis2 [5], and a common user interface frontend. Any specific device is integrated as a low-level controller (LoLeC) and can communicate with other constituents of the framework. To facilitate user controlled teleoperation, a Phantom Desktop haptic device and the AFM-controller are integrated as LoLeCs. Both LoLeCs initiate their communication via a handshake procedure arranged by the HiLeC and afterwards communicate directly via asynchronous socked-based data streams as shown in Fig. 2. The Phantom Desktop accepts user generated movements and streams positioning instructions to the AFM-LoLeC. It is the AFM-LoLeC's task to prevent potentially damaging movements and to operate the AFM only within its safety limits. The AFM-LoLeC introduces an artificial time slicing and sends back the actual AFM position as well as the measured force to the Phantom Desktop, where they are transformed into user accessible haptic feedback.

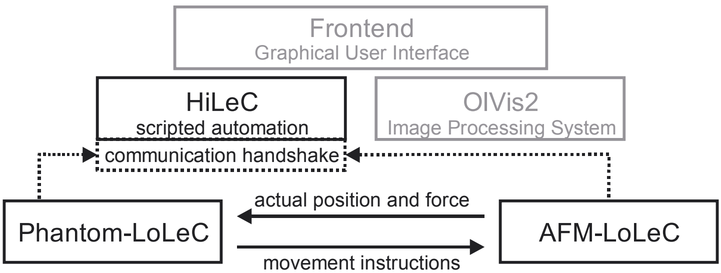

Figure 2: Schematic of the AMiR automation framework and the integrated LoLeCs for haptic device and AFM.

4 Teleoperated Nanomanipulation and Automation

Fig. 3 shows the teleoperated manipulation of melamin nanospheres with a diameter of 300 nm. The AFM was used to push the nanospheres across a silicon surface and arrange them in certain locations. The manipulations presented here have not been performed with full haptic feedback yet, but in a constant force mode where the AFM cantilever was pressed onto the silicon surface with a constant force by the AFM controller. The user was able to horizontally push the nanoparticles across the silicon surface with the AFM tip.

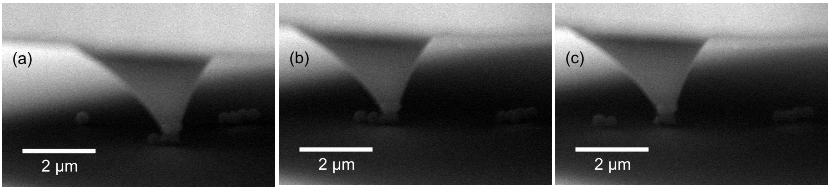

Figure 3: AFM tip observed by the SEM as it pushes nano-sized polymer particles across a silicon surface.

The implementation of direct haptic feedback is currently in development and sophisticated force mapping schemes have to be implemented to ensure feedback stability [6]. Since the automation framework contains a powerful visual analysis component capable of identifying and tracking objects, a full automation of micro- and nanomanipulation tasks is aspired and planed for the near future.

References:

[1] T. Fukuda et al.: Assembly of nanodevices with carbon nanotubes through nanorobotic Manipulations, *Proc. IEEE,* **91**, 1803 (2003)

[2] Y. J. Yun et al.: Manipulation of freestanding Au nanogears using an atomic force microscope, *Nanotechnology,* **18** (50), 505304 (2007)

[3] H. Xie and S. Régnier, Three dimensional automated micromanipulation using a nanotip gipper with multi-feedback, *J. Micromech. Microeng,* **19**, 075009 (2009)

[4] D. Jasper, et al.: "Towards automated robotic nanomanipulation systems," in Proc. of IIEEE/ASME Int. Conf. on Adv. Intelligent Mechatronics (AIM), 2009

[5] T. Wortmann et al.: "Image processing architecture for real-time micro- and nanohandling applications," in Proc. of MVA2009 IAPR Conference on Machine Vision Applications, 2009.

[6] A. Bolopion et al: "Analysis of stability and transparency for nanoscale force feedback in bilateral coupling," J. Micro-Nano Mechatronics, **4** (4), 145 (2009).