Exchange Grant
Electronic effects in friction force interaction of semiconductor nanostructures

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Scientific report on completion of the research visit of J. Prikulis to Institute of Physics, Tartu University (Estonia) in October-November 2004.

Purpose of the visit

The purpose of the visit was development of a new type of instrument for measurement and control of the dynamic friction force acting on semiconductor and other nanostructures. The design of the new instrument was based on the recently developed scanning probe microscope integrated in a transmission electron microscope (TEM-SPM). The sample holder was upgraded with a piezoelectric resonator for excitation of high frequency lateral vibrations. A computer controlled electronics module was developed for excitation and detection of oscillations. The software was made compatible with the existing SPM controller.

Description of the work carried out during the visit

The design of the dynamic force TEM-SPM includes a series of precision mechanic, electronics and software development tasks. As a first step we evaluated a number of piezoelectric resonators from different manufacturers to meet the requirements set by the experimental conditions inside the TEM. (Compact size, minimal magnetism of the mount, vacuum compatibility, reliable attachment of electrodes, etc.) Then a miniature holder with three electrical connections (two for driving the resonator and one for applying a potential to the sample) was produced for easy insertion of the selected model of quartz tuning fork.

A custom electronics module has been developed and assembled. It consists of a precision generator with frequencies tunable in 0.02 Hz steps, and a high speed lock-in amplifier, which can operate up to 10 MHz. The electronics module was integrated in the existing VXI based SPM controller. In addition, a small preamplifier was designed and placed close to the SPM holder, in order to reduce the noise and the effects of parasitic capacitances in the electric connections.

The SPM controller software was upgraded with drivers for the new electronics module. User interface functions for frequency tuning and data acquisition were also added.

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The developed mechanics, electronics and software were tested inside TEM and in air using the shear-force configuration of AFM.

Description of the main results obtained

During this visit the basic prerequisites for studies of the dynamic friction force interaction in nanostructures were established. The developed instrument allows simultaneous tuning and measurement of several parameters (frequency, sample potential, distance between nanoobjects, shear-force damping, contact current, etc.) while directly observing the system behavior in TEM.

The system test inside TEM showed that the oscillations can be easily observed as edge broadening in the TEM images. The oscillation amplitude can be measured with high accuracy, since the blurred region has a sharp borders, due to zero velocity at the oscillation endpoints.

We also tested the system in air by driving a shear force AFM and obtained topography images of structured gold film. This indicates that the system is fully capable to operate in constant hight feedback mode as a dynamic force AFM inside TEM.

Future collaboration with host institution

The collaboration between the Institute of Chemical Physics in Riga and Institute of Physics in Tartu will certainly continue in future, as we believe that the developed instrument will generate many interesting scientific results.

The long term goal of collaboration between the two institutes is development of nanomechanical devices based on controlled force interaction. As a next step we will study the dynamic force effects in individual semiconductor (Si, Ge) nanowires and carbon nanotubes.

Projected publications/articles resulting or to result from your grant

To our knowledge the developed dynamic force TEM-SPM is a unique instrument in the world. We plan to report the design and acquired results in the ESF Fourth Nanotribology Workshop in France in June 2005. At this moment, however, it is too early to predict what type of publication will result from the work, as the research will be continued.