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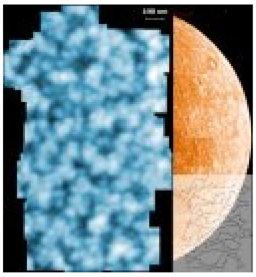
Autonomous operation of scanning probe microscope for space research



FOS scanning

A scanning probe microscope (SPM) mounted on board a spacecraft allows for the study of various surfaces at micrometer to nanometre scales. The SPM application in extraterrestrial research is rather promising in that it is a lightweight, compact, and reliable device that supports multiple measurement modes and has low power consumption and high spatial resolution. Thus, the SPM can be used for the study of regolith samples, rocks, minerals, space debris, and micrometeoroids, and can aid in the search for traces of extraterrestrial forms of life. It will also support investigations of the properties of materials, crystal growth, and biomolecular reactions, and help to implement nanotechnological operations in microgravity conditions. In May 2008, the NASA's spacecraft Phoenix, with a scanning probe microscope installed, landed softly on the surface of Mars and started microscopical investigations of the planet soil.

A scanning probe microscope is able to measure topography with atomic resolution. Moreover, it can modify the topography atom-by-atom, which permits considering this instrument as one of the basic tools of nanotechnology. However, the existing microscopes and the methods to control them are still far from perfection. In particular, a critical unit of today's SPMs is the probe positioning system being influenced by many negative factors: external vibrations, noises, thermal drifts, nonlinearity, hysteresis, creep, and parasitic cross-talk couplings of the used piezomanipulators. Those factors impact on the precision, the reliability, and the resolution of measurements. The appearing distortions cause wrong interpretation of experimental data and restrict the application field of the microscope.

At present, the problem of acquiring the adequate image of surface topography is being solved by means of compensating/correcting models describing the corresponding distortion and/or closed-loop measurement systems equipped with linear position sensors.

To obtain the adequate image of surface topography, Russian scientist Rostislav V. Lapshin from the Institute of Physical Problems suggested a new approach called feature-oriented scanning (FOS). Applying a real-time surface recognition, counter movements, and some other techniques, repeated scanning of small neighborhoods of surface features located in the vicinity of each other are carried out. After that, the searched for topography image, free of noises and distortions, is assembled from the acquired fragments. In the method suggested, topography features of a surface are used as the reference points.

FOS method provides the measurement precision of lattice constants and crystallographic directions increased by orders in comparison with the conventional scanning. The method provides accurately localized tunneling and atomic-force spectroscopy measurements with high signal-to-noise ratio. Moreover, according to the author of the method, the feature-oriented scanning makes it possible to perform “delicate” manipulations with separate nanoparticles, molecules or even atoms at room temperature.

The analysis carried out at the Solid Nanotechnology Laboratory, where the scientist works, showed that the method of feature-oriented scanning that had proved successful in Earth conditions may also help solve a number of problems of using a scanning probe microscope in space – at a near-Earth station or for planet research. The point is that beside much higher measurement precision and spatial resolution, FOS permits to notably decrease the SPM sensitivity to temperature variations.

Furthermore, the SPM under feature-oriented scanning control becomes a free-running instrument able of self-testing, self-adjusting and self-calibration. Interestingly, the trajectory of the microscope probe movement while feature-oriented scanning is not defined beforehand, it is actually being built dynamically during the operation. The behaviour of a microscope probing some unknown sample surface becomes similar to the one of an autonomous rover when it moves across an unfamiliar surface of a planet.

More details may be found in June issue of Astrobiology journal (volume 9, number 5, pages 437-442, 2009).

Source: Institute of Physical Problems, Russia