Non-hysteretic positioner for nano-lithography and cryogenic *in situ* adjustable nano-junctions

Benjamin Thomsen and Jesper Mygind*, Department of Physics, B309, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark.
*email: myg@fysik.dtu.dk

Here we describe a novel motor, which is capable of non-hysteretic (reversible) positioning of a sample in three orthogonal directions (x, y, and z) with nanometer resolution both at room temperature and at cryogenic temperatures. The motor can translate the sample ± 1.5mm in the x-y plane and ± 2mm in the z-direction and within this range park the sample at any position in firm contact with the motor body (zero voltage on the piezo stacks).

The motor is integrated with a small specially designed head, which except for modifications necessary for cryogenic operation assembles a standard insert for Scanning Probe Microscopy (SPM). The SPM head faces the sample stage and consists of a conventional piezoelectric x-y-z tube scanner carrying either an STM tip (STM-head) or an AFM cantilever (AFM-head). With the sample parked in fixed position by the x-y-z motor the SPM head allows for fine positioning and scanning with atomic precision. A new millikelvin AFM head is under construction. It utilizes single mode glass fibers both for supplying the laser beam focused onto the cantilever, and for transmitting the reflected beam back to the room temperature detection system.

The x-y translation of the sample is facilitated by two sets (A and B) of piezo stacks (“legs”) glued onto a thick brass plate. The legs are placed evenly (60 degrees) in a circle with diameter approx. 20mm (see Fig. 1). Each leg consists of three 5mm by 5mm piezo stacks (“legs”), each with four x-shear plates glued in series with four y-shear plates and a multilayer z-stack. On top and bottom of each leg is glued a 5mm by 5mm Al2O3 plate. After gluing the six legs are optically polished to obtain same length. The operational relies on the well known louse principle, modifyed to a 6 leg configuration, where in every step 3 legs are lifted fully free from the polished quartz or sapphire surface before they are jointly moved to the new position. The z translation utilizes a similar working principle that enables a linear motion.

The motor can be used as a coarse positioning device, which with a (large) number of (up to a) micrometer long x-y-z steps rapidly brings the selected region of the sample in first contact with the probe tip in the SPM head. Contact is registered as either the first small tunnel current in the STM head or the small change in the deflection of the laser beam focused on the cantilever in the AFM head. Maintaining the contact the motor then parks the sample with zero voltage on the motor piezos. Here the galvanic contacts to the wires leading to the motor piezos may be disconnected, so that the electrical noise from the high-tension amplifiers cannot induce mechanical disturbances in the sample position. After having parked the sample x-y-z scanner tube unit regulates the position of the STM tip or AFM cantilever. Actually, one may use very small x-y-z steps in the motor to adjust the tip-sample distance so that also the off-set voltages applied to the tube scanner are near zero. Recent experimental results will be reported on.

Presently we are investigating the creep of the motor piezos and the tube scanner at low temperatures. For the non-scanning applications eg. nano-lithography and nano-junction fabrication it is necessary to have a linear dependence of the tip position on the piezo voltage. However, noise in the “feed back” optical loop used is estimated to induce a 1-10 nanometer fluctuation in the spatial resolution. In many cases this limits the accuracy and for better precision one has to “live with” the creep in the piezos. The optical servo system will be briefly described.

Together the motor and the SPM head form an instrument, which enables atomic resolution both in the scanning modes and at fixed positions. This allows for a wide spectrum of applications, such as nano-lithography and studies involving *in situ* adjustable junctions. A particular advantage of cryogenic operation is that thermal fluctuations in the piezo-electrical materials are very small. The disadvantage is that the piezo-electrical constants at e.g. 4.2K are reduced to about 20% of the room temperature values. The motor mounted with an SPM head is very compact and fits into the 34mm diameter bore of a standard (Oxford) millikelvin 3He/4He cooler placed in the center of a 10 tesla superconducting magnet.

The motor and the SPM head are jointly run by a computer (with an A/D interface input/output card) in conjunction with a standard SPM controller (Veeco, Digital Instruments). Depending on the controller and the software one may utilize all the standard modes of operation, eg. tapping mode.

Presentation: Oral, 20 min. by Jesper Mygind