A versatile, fully-integrated dual PLL controller for SPM with application to magnetic force microscopy

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A fully integrated Scanning Probe Microscope (SPM) controller featuring single and dual phase locked loops (PLL) has been developed by NanoScan. Here, its outstanding properties are briefly illustrated by application examples from our range of high and ultra-high vacuum SPM's.

This modular SPM controller features all the necessary components to control a vacuum SPM. All standard SPM modes are available: from STM to non-contact AFM, and also Kelvin probe force microscopy.

The controller is matched to drive both tube-scanners and fully-linearized flexure stages. The High Voltage Amplifier is specifically designed for the needs of the tube-scanner user, with ethernet controllable gains up to ±400V, attenuations and offsets enabling the use of the full range of controller output in an image size which can be arbitrarily small.

The Piezo-Motor Controller can combine fast sample stage drive with 20-nm accuracy positioning. This feature is taken advantage of with the unique *Point-Approach Mode* to record topographical data over long distances.

Both interferometric and optical beam deflection for cantilever oscillation detection are supported by the controller. Stand-alone hardware components are available: either a homodyne interferometer with adjustable outputs, or a four-quadrant beam deflection detection electronics.

To demonstrate the flexibility of the controller, a case study is presented where the controller is running a low temperature magnetic force microscope in a variable magnetic field. The sample studied is an example of the so-called bit-patterned media (BPM). BPM is one potential candidate to replace the current continuous magnetic recording media once the limit of bit density has been reached.

Bit-patterned media consists of magnetic islands which are physically discrete from one another. This allows more magnetic bits to be packed into the same area. Physically structuring the media leads to many challenges, one of which is the wide switching field distribution (SFD) of the array of islands. Ideally, the SFD would be zero, and all islands would flip their magnetisation at the same field. In practise, there are many parameters which lead to an imperfect SFD such as morphology and strain.

This study investigates the SFD of BPM with island size 50 nm using magnetic force microscopy in an applied magnetic field. An array of islands was imaged and the SFD determined from the series of MFM images taken in increasing magnetic field. Carrying out the same series of in-field MFM measurements at room temperature, low (10K) and elevated (360K) temperatures, the temperature dependence of the SFD, along with the coercivity of the islands can be elucidated. Both the SFD and the coercivity increase with increasing temperature.

The same array was subsequently imaged in non-contact mode with a non-magnetic tip to elucidate the size and local morphology of the islands.