Design of Digital Instrumentation for Scanning Probe Microscopy

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Abstract

A scanning tunneling microscope with a focus on digital instrumentation has been built. The aim of this project was to allow a digital signal processor full control over all essential microscope variables, especially simultaneous control of the vertical and horizontal tip position.

Due to the fact that its operation is controlled by software, this system offers convenient operation and considerable flexibility, allowing different modes of operation, such as topographical and spectroscopic scans. Presently this microscope is the only one in New Zealand that allows the operator full software control over the tip position and bias voltage, thereby allowing it to become a powerful research tool.

Atomic scale images on graphite were successfully recorded. The spatial resolution of the microscope was estimated to be 5 pm vertically and 40 pm horizontally. Two different imaging methods were demonstrated on a gold sputtered TEM grating with a scan area that was larger than $4\,\mu\text{m} \times 4\,\mu\text{m}$. One method has variable horizontal scan speed, while the other method can possibly be used for nanolithography. Both show the flexibility of this system.

Although digital electronics is often perceived as being slower and noisier than analog electronics, in this instrument it did not decrease the data acquisition speed nor did it reduce the signal-to-noise ratio. The bandwidth of the closed-loop controlled microscope is currently about 1 kHz, limited by the bandwidth of the current-to-voltage converter, an analog component. The resolution is limited by the large gain of the high-voltage amplifiers used to drive the actuators. With a faster current-to-voltage converter and a reduced high-voltage amplifier gain, a bandwidth of 8 kHz should be possible with a vertical resolution of less than 2 pm and a horizontal resolution of 10 pm.

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