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Paper Session I-A - Development and Testing of Scanning Probe Microscopy for the Zero-G Environment and ISS

R. M. Branly
Broward Community College

R. Friedfeld

E. Howard

S. Parker

R. Williams

Development and Testing of Scanning Probe Microscopy for the Zero-g environment and International Space Station

R.M. Branly, R. Friedfeld, E. Howard, S. Parker, R. Williams

The Association of Small Payload Researchers (ASPR) has established a partnership and collaborative effort to develop a Scanning Probe Microscope for ISS. The initiative seeks to deliver a Facility Instrument available to the entire ISS community. ASPR brings university and independent researchers together to a payload engineering forum that unites the investigator's academic disciplines. The association has begun testing an atomic force microscope (AFM) aboard the KC-135 reduced gravity aircraft. The initial work included a collaboration with educational organizations that has expanded to include partnerships with space businesses and international small payload developers. The initial trials of a prototype AFM unit in zero gravity proved successful.

Overview

The International Space Station (ISS) will provide the ability to synthesize new materials and to manufacture new products in space. For example, semiconductor crystals and protein crystals, which have important applications to computer technology and biotechnology respectively, can be grown to a greater degree of perfection in microgravity than on earth. The Space Station will provide a platform that can offer months or even years of microgravity conditions at a time. Among the earliest commercial products we could expect to be manufactured on the ISS would be high-purity semiconductor crystals and large protein crystals with enhanced crystallinity.

In order to support a crystal-manufacturing platform in space, it will be necessary to have on the ISS certain instruments that can be used to characterize samples while still in orbit. An ideal instrument for this application would be one that can resolve the structure of crystals down to the atomic scale, is small in size, has low power requirements, and is operationally clean. Such an instrument can be developed in the form of a Scanning Probe Microscope (SPM) for the microgravity environment, or a microgravity SPM system.

Scanning Probe Microscopy is a general term used to describe a type of microscopy in which a local probe is raster scanned over a sample of interest. As the probe is scanned across the sample, a local interaction between the probe and sample is measured. Scanning Probe Microscopes (SPMs) include the Scanning Tunneling Microscope (STM), the Atomic Force Microscope (AFM) and many other types that have been developed from these earlier predecessors.

The ISS is being assembled with various experimental apparatus and instrumentation in mind; however, a scanning Probe Microscope (SPM) has not been intended. It is an ideal instrument for materials processing in space where direct atomic resolution can be obtained of crystalline materials as they form instead of returning them to Earth for analysis.

SPMs are generally very sensitive to mechanical and acoustic noise, especially when imaging at the atomic scale. This usually requires some degree of vibration isolation. The instrument can be isolated from acoustic vibration by placing it under a vacuum. The mechanical vibrations usually require either an elaborate passive vibration isolation system or a sophisticated electronic active vibration isolation system. Because of the scientific benefits of installing an SPM on the ISS, an experiment was devised to determine the effectiveness of such an instrument in reduced gravity. In the experiment, an AFM was mounted to an active vibration isolation system. The system minimized mechanical resonance. A vacuum was produced around the

instrument to eliminate acoustic noise. This was achieved by mounting a hollow acrylic cylinder directly to the vibration isolation unit and evacuating the air inside the chamber.

Since the AFM requires minor adjustments during operation, radio controlled servos were used to adjust certain controls remotely. It allowed the adjustment of the device without any direct contact from the operations team, thus eliminating outside vibration. When reduced gravity was achieved, the operations team imaged samples at the micrometer range (1 micron gold grating) and at the 50 - 100 nanometer range. The force curves corresponding to the images were recorded along with the accelerations. The force curves and images were acquired according to preset configurations. The experiment was successful. The noise in the images was minimal aboard the KC-135.

The Flight Hardware

Through Stephen F. Austin State University a Digital Instruments commercially available AFM was flown aboard NASA's KC-135 reduced gravity aircraft. The equipment rack was bolted to the floor of the aircraft carrying all the necessary equipment for semi-automated operations. The lessons learned have guided the ASPR design team's approach for the development of a unit that will fit in a Middeck Locker equivalent space aboard the Space Station Enterprise commercial module for 2005.

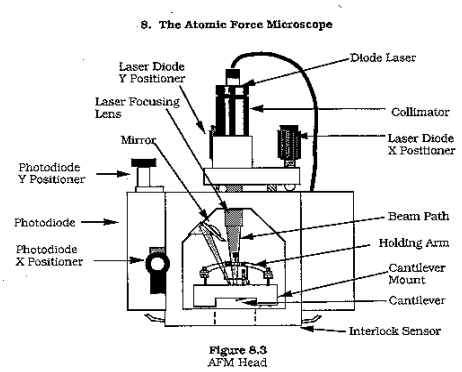

Figure1: AFM Head showing Laser Diode/Detector layout
(Diagram courtesy of Digital Instruments)

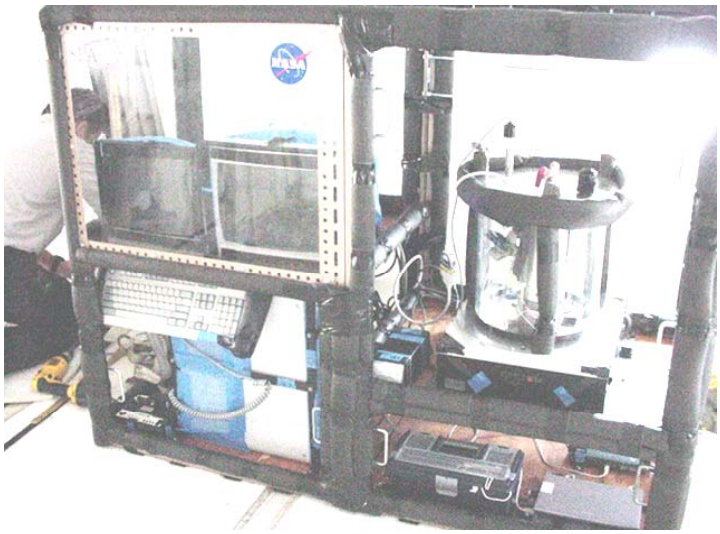

Figure 2: The KC-135/AFM Experiment aboard the aircraft prior to flight

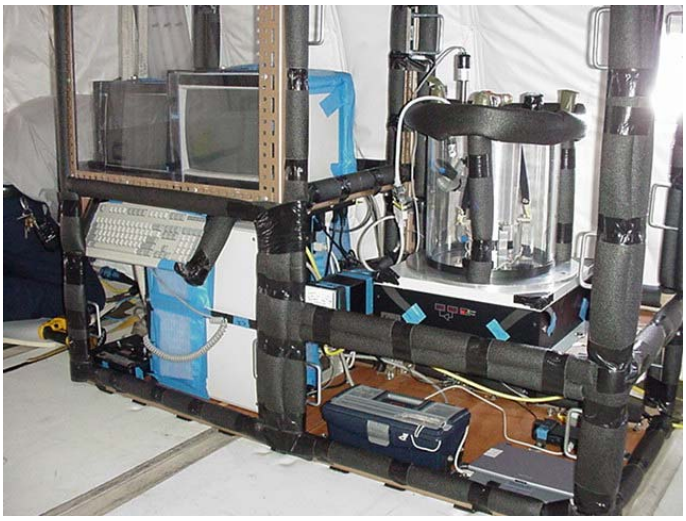

Figure 3: Another view prior to flight

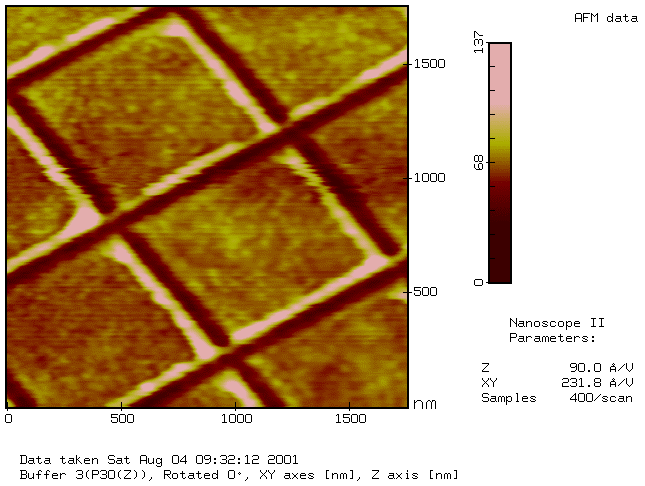

Figure 7: Image of Gold Calibration grating obtained in flight.

The future

The ASPR team continues to work on the design and miniaturization of the components for an ISS unit. The association will assemble science and engineering teams of interdisciplinary interests, with the aim of making the microscopy facility available to the entire ISS community.

References

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