Observation of Sample Surface SPM Supports Nanotechnologies

Nanotechnologies play an important role in fields of research such as thin films, high polymer materials, carbon nanotubes, and DNA. Scanning Probe Microscopes (SPM), and in particular Atomic Force Microscopes (AFM), are used as the surface observation technology of choice for the nanometer-order thin films essential for increased storage densities.

AFM Detects Forces of 10^{-9} Newton

Scanning Probe Microscope (SPM) is a generic term for a device that moves an extremely fine tip near the sample surface and exploits the interaction between the sample and the tip to reveal sample-surface topography at high magnification. The most commonly used type of SPM at present is the Atomic Force Microscope (AFM) that exploits the so-called atomic force. A variety of related technologies and devices are based on AFM. The principle of the AFM is described below.

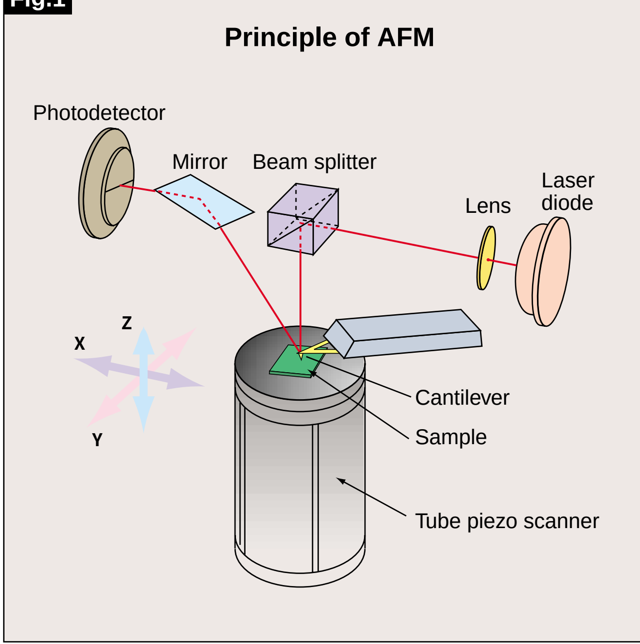
Fig. 1 shows the optical lever principle that is typically used for an AFM. The tip is formed at the end of a tiny, flexible cantilever. Atomic forces acting on the tip in close proximity with the sample surface are converted to deflections of the cantilever, which are detected. Laser light focused on the upper surface of the cantilever reflects from a mirror into a photodetector, which detects cantilever deflections. Typical dimensions of this system are a 200µm cantilever length, 0.1µm cantilever thickness, 3µm tip length (at the end of the cantilever), and 20nm tip radius of curvature. The tip is separated from the sample surface by no more than a few nanometers enabling detection of tiny nanoNewton-order interatomic forces.

A piezoelectric scanner scans and controls the sample in three dimensions at an accuracy of 0.1nm or better. It creates a topographic image of the sample surface by tracing the minute surface shapes (X and Y axes) while providing feedback control to maintain a constant cantilever deflection (Z axis).

The AFM offers the following three benefits.

- Simple, high-magnification observation in air
- Direct observation of insulating materials
- Accurate measurement perpendicular to sample surface

Fig.1



Broadening Range of Applications Including Thin-film Evaluation and New Material Development

Thin films play an important role in nanotechnology. For example, Diamond-like Carbon (DLC) films have been important for many years as the protective film on storage media, such as hard disks. The increased storage density in recent years demands nanometer-order thin

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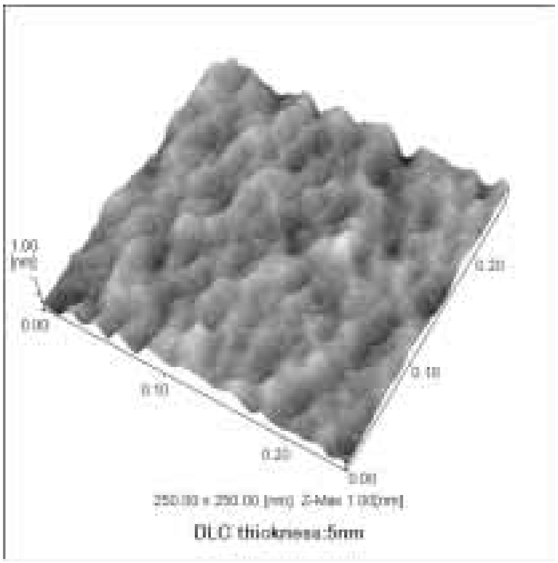
Fig.2



AFM Image of a DLC Film
Observed area: 250nm x 250nm

Fig.3

SPM-9500J3

films and has led to attention being focused on productivity and reliability in evaluation. For DLC film evaluation, SPM is employed to measure surface roughness and height differences and to evaluate film quality, in addition to observation of surface topography (Fig. 2). SPM is commonly used for organic films, conducting films, and dielectric films as well as DLC films.

The use of high-polymer films has attracted interest recently. The unique structure of high-polymer materials is known to determine their material characteristics; lamella and phase-separated structures are typical examples. SPM is widely applied to observation and evaluation of these nanostructures in R&D work to develop new materials.

SPM is also used in nanowire research, typified by carbon nanotubes and DNA, and in nanomachining to cut grooves in substrates. SPM is an essential tool for nanotechnology and will more than likely be used in more fields in the future.

Shimadzu SPM-9500J3 Offers High-resolution Observation and Excellent Expandability

The Shimadzu SPM-9500J3 (Fig. 3) is the latest SPM unit, developed to allow any user to easily conduct high-resolution observations and to offer the expandability to meet a diverse range of customer requirements. It is highly acclaimed both in Japan and overseas. Operability is excellent; one-touch sample replacement with the unique, patented head-slide mechanism, fully automatic tip approach to the sample surface, and automated observation operations combine with effective hardware and software to allow SPM observations within a few minutes of loading the sample.

In addition to providing high-magnification AFM imaging of surface topography, the SPM-9500J3 is compatible with many measurement modes, including viscoelasticity measurements, magnetic force microscope, electrical force microscope, adhesion force measurements, ultra micro hardness measurements, and micro-scratch measurements. Installing the SPM unit in the optional environmentally controlled chamber upgrades the unit to an environmentally controlled SPM, which offers sample adjustment and SPM imaging in a controlled environment (vacuum, special gas, temperature and humidity, sample heating or cooling, gas spraying, light irradiation etc.).

µTAS Technology Pioneers the Way to Greater Analyzer Compactness

Nanotechnology Opens Up the Future of Analysis Technology – Smaller, Lighter, Cheaper Analyzers.
An Introduction to µTAS Technology and Shimadzu Related Activities

Fig.1

What is µTAS (Micro Total Analysis System)?

Significant research and development has been conducted around the world into µTAS technology, which has been nicknamed "Laboratory on a Chip." µTAS research employs MEMS (Micro Electro Mechanical Systems) technology to create ultracompact analyzers by fabricating the major analyzer components and integrating all analysis functions from sampling to detection onto a substrate (Fig. 1). µTAS offers a wide range of benefits.

- More compact analyzer systems (space savings)
- Shorter analysis times (time savings)
- Smaller sample and reagent volumes and reduced wastage (resource savings)
- Automated pretreatment
- Lower system power consumption (energy savings)

Smaller, lighter, and cheaper analyzers could be applied across a range of fields, allowing simpler clinical diagnosis and bedside monitoring in medicine and on-site analysis for environmental monitoring.
Active research by many organizations has brought microchip electrophoresis close to practical application and some commercial products are already available. Shimadzu has developed the MCE-2010 electrophoresis system using a quartz-glass electrophoresis chip as a commercial product (Innovation No. 27, 2000).

Nanotechnology and µTAS

Realization of Nanotechnology

µTAS chips are processed with an accuracy of µm-order (1µm = 10^{-6}m) using MEMS technology. The channels on the electrophoresis chip (50 µm width x 20 µm depth) handle volumes in the order of nanoliters (10^{-9}L) or picoliters (10^{-12}L)(Fig.2). Nanometer-order control is required to fabricate such chips. The attempts at separation analysis using nanoscale structural elements can be considered one "realization of nanotechnology."

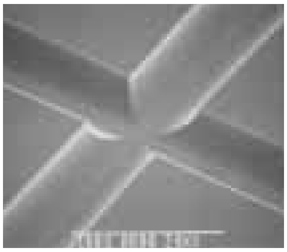


Fig.2

Channels on an electrophoresis chip observed using a scanning electron microscope.

Handling Nanoscale Biomolecules with µTAS

Application of µTAS technology in the nano-technology field is on the increase. For example, µTAS has made the measurement of individual molecules a possibility while the real-time observation of the electrophoresis status of DNA molecules(1) and the measurement of single molecules employing a new method using the thermal lens effect(2) also have been recently reported.
These are new applied technologies based on the ability of µTAS technology to precisely handle minute flow volumes. The range of application of µTAS technologies is likely to further expand in the future as observation, measurement, and analysis of objects at the molecular level become increasingly important.

The World of the Nanosecond

As described above, µTAS and the nanotechnology field are closely related by size but the nanosecond time increment is also significant for the objects handled by µTAS. For instance, the stimulus response of the constituent cells of our bodies occurs on a nanosecond time scale, requiring high-resolution detectors to detect it. This topic is being tackled as a national research project, and great success is anticipated.

Future Protein Analysis with µTAS

The completion of decoding the human genome means that we now essentially possess the blueprint of our own design. The next topic is likely to be deciphering the structure and function of proteins that form our bodies according to this blueprint. µTAS is eminently suited to this task. The emphasis is shifting from DNA analysis to protein analysis. However, protein analysis is more complex due to protein denaturation and environmental sensitivity. In addition to conventional electrophoresis, the analysis of proteins requires new technologies to introduce samples into the mass spectrograph. Applications should be found for µTAS in previously problematic high-speed analysis, automating the pretreatment of minute samples, function integration, and the demands of new analytical methods.
Shimadzu is sparing no effort in fusing its accumulated analyzer and life-science-related technologies, newly developed MEMS technology, and the underlying µTAS technology to pioneer these and other new technical fields.

(1) M. Ueda, et al., Trans. IEE JPN, 119-E (1999) 460-463
(2) T. Kitamori, et al., Proceedings of the µTAS '98 Workshop, Banff, Canada Oct.1998, 295-298

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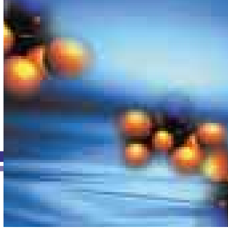


Nanotechnology Devices Provide Background Support to Semiconductor Processing SALD-7001 Laser Diffraction Particle Size Analyzer

The sophisticated Shimadzu SALD-7001 supports current development of nanotechnology across a wide range of advanced fields, including the electronics industry.

Nano-Scale Particle Size Distribution Measurement

Integrated circuits such as LSIs and ULSIs (ultra large scale integration) are formed by incorporating circuits onto silicon wafers through photolithography and other methods. Higher degrees of integration demand sub-micrometer levels of wafer surface irregularities. Consequently, a new hybrid polishing method called CMP (Chemical Mechanical Polishing) uses a chemical wafer abrasive in addition to mechanical polishing to create a smoother wafer surface.

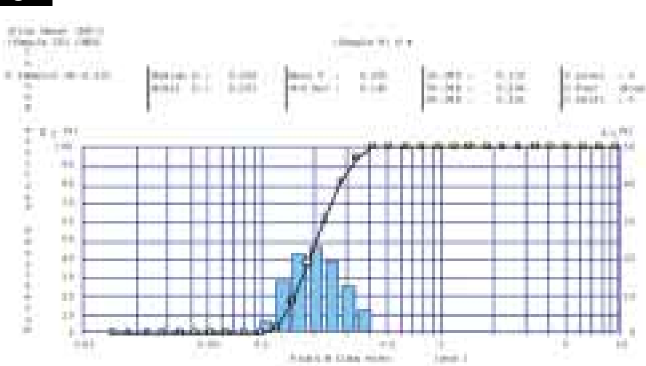
Chemical purity and the size of constituent particles are important characteristics of these abrasives, which must maintain a controlled particle size distribution through the sub-micrometer and nanometer ranges. The Shimadzu SALD-7001 Laser Diffraction Particle Size Analyzer (Fig. 1) is ideally suited to measure particle size distribution in these ranges, which is difficult for conventional analyzers. The SALD-7001 is the first analyzer in the world to employ a short-wavelength blue laser as the light source, which combines with a specially designed optical system to measure particle size distributions down to 15nm. Figs. 2 and 3 show a comparison of the particle size distributions of defective and non-defective CMP slurries. In addition to determining the particle size distribution through the sub-micrometer and nanometer ranges, these measurements can detect the existence of defective particle size distributions in the micrometer and larger ranges.

The SALD-7001 can truly be described as a nanotechnology device providing background support to semiconductor processing.

Fig.1

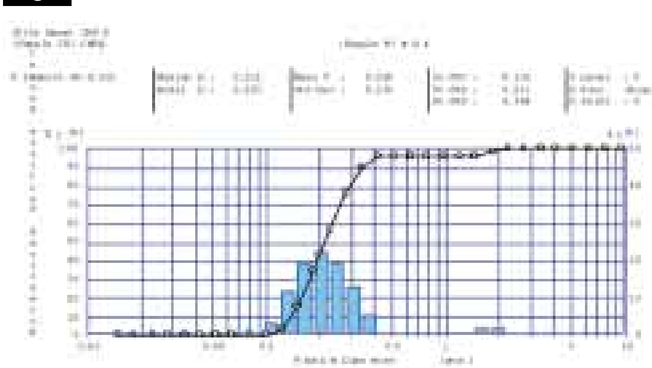
SALD-7001

Fig.2



Particle size distribution of non-defective CMP slurry

Fig.3



Particle size distribution of defective CMP slurry

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