**Research Project**: Nano particle reinforced composites for critical infrastructure protection

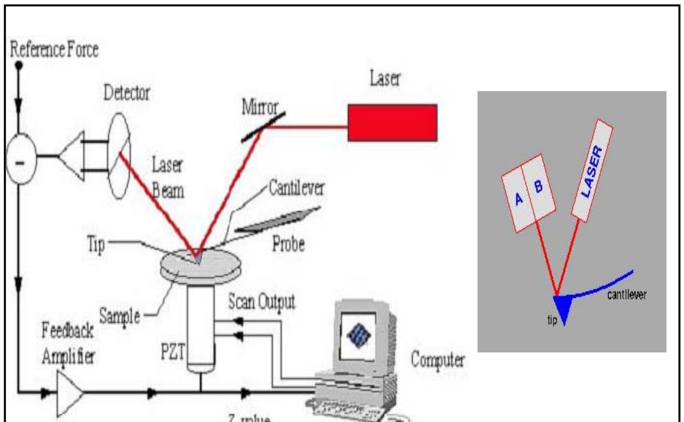
**Research Topic**: Atomic Force Microscopy (AFM)

### Problem

To gain understanding of the performance of nano-particle enhanced composite materials, such as fly ash and polymer enhanced concrete or carbon nanotube enhanced polymer, atomic force microscopy (AFM) is needed to examine the material structure at the nano level. The result can assist in the theoretical modeling by quasi-continuum theory, the computer simulation by molecular dynamics, and the interpretation of experimental observations.

### Approach

The AFM is based on the technology of sensing the interaction between an atomically sharp diamond tip and specimen surface as shown in the Figure below. It can characterize not only the surface characteristics, but also the mechanical properties, at nano-scale.



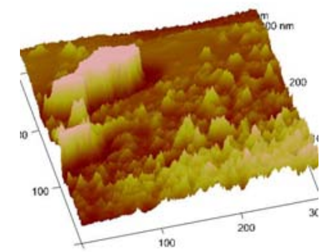

*Schematic diagram of Atomic Force Microscopy*

In this project, AFM is used as an imaging tool to evaluate the dispersion of nano particles in various matrices in order to study the topography of fractured surfaces and to get qualitative measure of particles adhesion. It will also be used to study local properties (modulus and hardness) of nano composites using indentation technique.

The dynamic mode of AFM, such as force modulation (FM), or scanning acoustic microscopy, by employing different character of tip-surface contact (constant or periodic) or cantilever dynamic regimes, have greatly expanded the capability of nano-mechanical mapping in comparison with static mode AFM. In FM-AFM the cantilever base is low frequency modulated while the tip is in contact with the surface. The cantilever exerts a force on the surface; the stiffer the area, the higher the cantilever deflection magnitude. The surface topography is determined from the feedback circuit, which tries to keep the average cantilever deflection constant. This procedure will be used to measure quantitatively the Young's modulus of CNT, nanoclay, graphite platelet or other polymer composite materials. Statistical analysis will be used to identify modulus values associated with the matrix, fiber and interphase. In this study, two sets of samples will be used: undamaged sample, and preloaded (pre-cracked) sample. This procedure, combined with numerical simulation, will be used to quantify the amount of damage. The atomic force microscopes that will be used in this study are Digital Instruments multimode scanners with Nanoscope IIIa and Nanoscope 5 controllers equipped with a variety of tips, which are housed in the Department of Chemical Engineering at the University of Mississippi. Topographic and phase images will be captured simultaneously by using tapping mode AF.

### Findings

This work is at the initial stage. At present, topographic images of 2.5% MWCNT/Nylon 6,6 with tapping mode AFM have been collected using Nanoscope IIIa AFM. A sample image is shown below. This and other images are currently being analyzed.



Atomic Force Microscopy of polymer nano composite.

### Impact

The Atomic Force Microscope is well suited for the characterization of nano-composite polymer materials when compared to traditional microscopes such as the electron and optical microscopes. Atomic force microscopes give direct 3-D measurements of the surface structure of polymers. Further, using material sensing modes such as lateral force and phase contrast, it is possible to differentiate the types of materials on a polymer surface which will help improve or validate theoretical modeling procedures.

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