ATOMIC FORCE MICROSCOPY (AFM) FOR SCIENTISTS

You are likely familiar with techniques such as optical microscopy and scanning electron microscopy (SEM) for imaging at the micron and nanometer scale, respectively.

Focusing on nanoscale to atomic level characterisation, there is another powerful tool that can be utilised called atomic force microscopy (AFM). While SEM uses the interaction of electrons with a sample to image its nanoscale surface features, AFM uses the forces between the nanoscale apex of a tip and the sample. This tip is positioned at the end of a cantilever and collectively, they are known as an AFM probe.

The probe is placed above the sample with the tip apex facing the sample surface. A laser is reflected from the tipless side of the cantilever onto a photodetector, as shown in the simplified schematic of an AFM system (Fig.1). The tip is scanned across the surface of the sample and the cantilever will deflect because of the force between the tip and the surface. The deflection will vary as the tip encounters surface features of different heights, which leads to a change in position of the laser beam on the photodetector. This change in position builds up an image of the sample surface topography at the nano- to atomic scale, which is output to a PC, as seen in Fig. 1. The colour bar represents the height of the features.

AFM has many advantages over SEM, as a nanoscale imaging tool. While SEM needs to be performed in vacuum, AFM can be conducted in a variety of environments, namely, ambient, liquid, and vacuum. Its ability to image in liquid means that it is suitable for the study of biological samples.

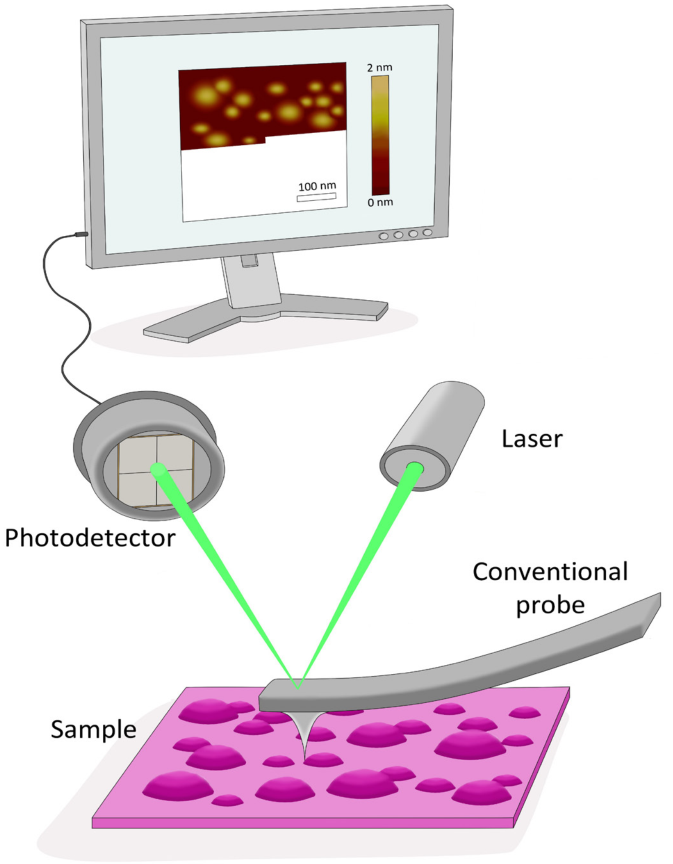

Figure 1: Schematic of AFM setup

Furthermore, SEM requires the sample under study to be conductive. Therefore, a non-conductive sample must be coated in metal to facilitate imaging. This special preparation of the sample is not required with AFM. With SEM, the resolution is limited by the size of the electron beam spot on the sample, which depends on the wavelength of the electrons and the system producing the beam.

On the other hand, AFM is determined by the sharpness of the tip, which can be manufactured to be much smaller than the electron beam spot size. Therefore, AFM produces higher resolution images than SEM.

Additionally, AFM is considerably more versatile than SEM. It can render a three-dimensional image of a sample surface with quantification of the surface roughness, whereas an SEM can only image in two dimensions. Finally, with modification, an atomic force microscope can measure the chemical composition, conductivity, electric field, magnetic structure, elasticity, and work function of a sample surface, whereas SEM can only determine chemical composition. However, it should be noted that SEM and AFM can act as complementary tools in materials characterisation.

AFM has been utilised in many STEM (Science, Technology, Engineering, and Maths) disciplines. For example, it has been used to image DNA [1], two-dimensional materials such as graphene [2], and the chemical bonds of single molecules [3], as shown schematically in Figs. 2 (a), (b), and (c), respectively.

Perhaps AFM would be useful in your research?

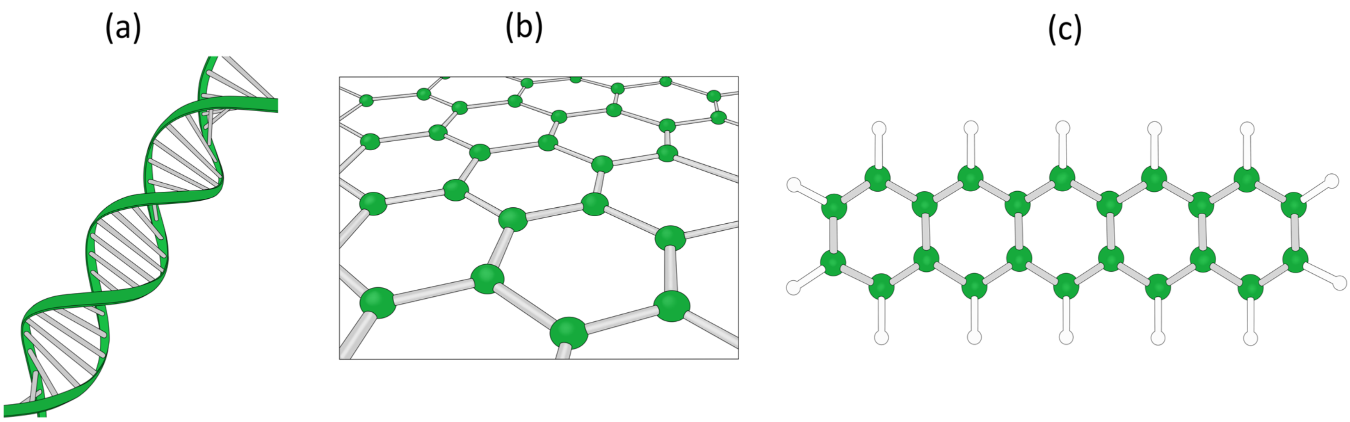

Figure 2: a) DNA, (b) graphene, and (c) single molecule pentacene

References

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[3] L. Gross, F. Mohn, N. Moll, P. Liljeroth, and G. Meyer, "The Chemical Structure of a Molecule Resolved by Atomic Force Microscopy," Science, 325(5944), pp. 1110-1114, 2009.