AFM Capabilities in Characterization of Nanoparticles: From Angstroms to Microns

Natasha Starostina and Paul West

Pacific Nanotechnology, Inc., 17981 Sky Park Circle, Suite J, Irvine, CA 92614

Abstract

Scanning Probe Microscopy (SPM), invented 25 years ago, is now routinely employed as a surface characterization technique. Atomic Force Microscopy (AFM) is the most widely used form of SPM, since AFM can be used in ambient conditions with minimal sample preparation. AFM measures three-dimensional topography profiles and images with unprecedented resolution from micron to sub-Ångstrom scales. AFM is well suited for individual particle characterization, especially for measurements of volume, height, size, shape, aspect ratio and particle surface morphology. Statistical distributions for a large set of particles can be generated through single-particle analysis techniques (i.e. ensemble-like information). Single-particle analysis techniques with AFM are generally more cost and time-effective than analysis with Scanning Electron Microscopy (SEM). AFM offers resolution that is comparable to or greater than SEM or Transmission Electron Microscopy (TEM). Also, AFM directly measures parameters such as height and volume and produces images that can be displayed in a 3D format.

Introduction

AFM has been successfully employed for surface topography characterization over the last two decades. IBM invented scanning tunneling microscopy (STM), which is considered the technique antecedent to AFM, in 1982.[1,2] STM requires samples to be electrically conductive, increasing the difficulty of imaging insulating samples. AFM was invented in 1986, to overcome the limitations of STM and broadened the base of applications for SPM. Comprehensive reviews of AFM are found in literature.[3-5]

In brief, AFM application capabilities can be summarized as following:

a) imaging in ambient conditions, in intervening media, and in ultra high vacuum (UHV),

b) sample preparation is minimal;[6] and,

c) it is possible to image physical properties of materials, such as magnetic, electrical, thermal, and mechanical parameters.

AFM capabilities include sub-Ångstrom vertical resolution, ~8 micron Z-range, ~80 microns XY-range. Typically, commercial instruments include many sensing modes, such as, contact, frictional, vibrating and vibration phase modes.[7] The goal of this paper is to show how AFM capabilities traditionally used in material science can be employed in the cosmetics industry. All AFM data shown in this paper was obtained on Light Lever Nano-Rp™ and analyzed with NanRule+™ image analysis software.

Application to hair

Healthy hair has a well-defined cuticle structure. The AFM images presented in Figure 1 show a 3D comparison between unprocessed hair and color-processed one. Both images have a scan size of 41x41microns. The AFM images show the dramatic difference in surface topography between the two strands of hair. Cuticles layers are well-defined on unprocessed hair. Surface roughness measurements were taken over an area of about 6 x 6 microns on a single cuticle, for each sample. The root mean square (RMS) of the surface roughness was $RMS_{processed}$= 94.2nm and $RMS_{unprocessed}$= 84.9nm. Material sensing mode reveals the material contrast of a single cuticle.

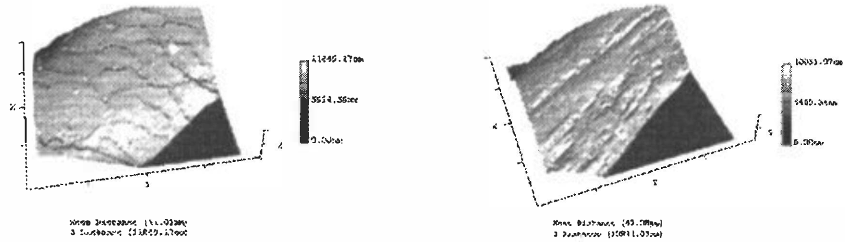

Figure 1. 41x41micron 3D AFM images of unprocessed (left) and processed (right) human hair structure.

Application foundation powder

Figure 2 shows foundation powder deposited on the gl-substrate. Particles or particle agglomerates can be characterized in terms of radius, height, volume, and aspect ratio. A larger scan reveals that most of the deposited particles are 103-317 nm. A magnified image of 3x3 μm shows the morphology of nanoparticles. The circles shown on figure 2 (right) indicate how particle radius being calculated.

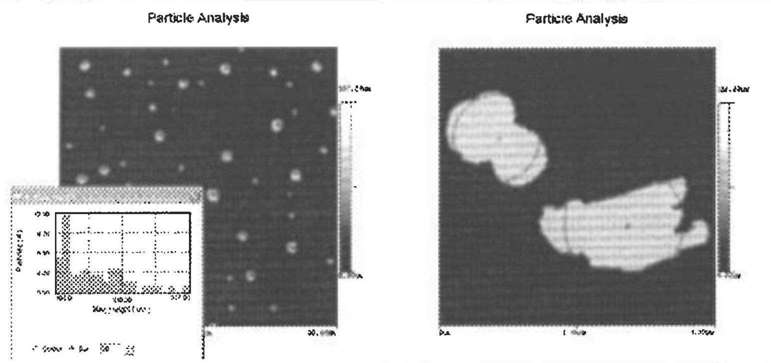

Figure 2. Height distribution for foundation powder particles. 40x40μm image is on the left; 3x3μm is on the right .

Material sensing or vibrating phase imaging modes compliment topography data (Figure 3). Material sensing mode produces an image that contrasts the difference in elastic properties. The foundation powder particles are softer than substrate. Phase mode images of particles can be analyzed in the same way as topography images. Particles need to be outlined, counted, and measured to generate particle size, area, and perimeter distribution data.

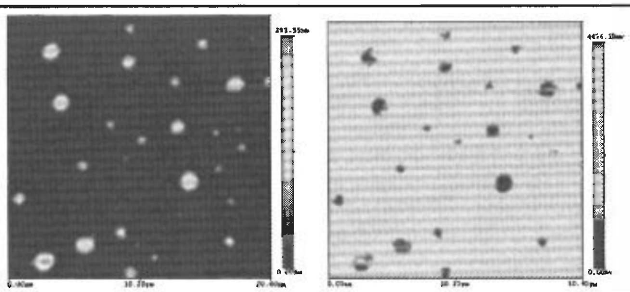

Figure 3. 20x20 μm topography (left-hand side and phase mode(right-hand side) images of foundation powder. Images obtained simultaneously.

Conclusions

Applications for the AFM in the cosmetic industry include particle characterization and surface roughness and texture measurements. Major advantages of using AFM in the cosmetic industry are that it is easy to use and requires minimal sample preparation.

References

1.G. Binning, C.F. Quate, Ch. Gerber, E. Weibel, *Phys.Rev.Lett.* **49**, 57-61 (1982)
2.G. Binning, C.F. Quate and Ch. Gerber, *Phys.Rev.Lett.* **56**, 930-933 (1986)
3.D.Bonnell, *Scanning Probe Microscopy and spectroscopy*, Wiley-VCH, 2001
4.S. Dror, *Scanning force microscopy: with applications to electric, magnetic and atomic forces*, Oxford University Press, 1994
5. J.C. Hooton, C.S.German, S.Allen, M.C.Davies, C.J.Roberts, S.J.B. Tendler, P.M.Williams, *Pharmaceutical research*, **21**, 953-961, 2004
6.N.Starostina, P.West, *Proceedings of the 33 annual international waterborne, high-solids, and powder coating symposium*, 307-320, February 2006
7.P. West, N. Starostina, *Advanced Materials & Processes*, 35-37, February 2004