Comparison of SPM and SEM Images

When comparing SPM (Scanning Probe Microscopes) and SEM (Scanning Electron Microscopes), SEM also has a long history, and has reached an overall state of perfection. In contrast, SPM is in a state of development, with spectacular advances not only in hardware and software development but in application technology as well.

Further, rather than simply following in the footsteps of SEM, SPM promises advances in completely new directions. This is because while the names suggest similar equipment, "Tip probes" and "Electron probes" actually have a bilateral character, sharing both similar and completely dissimilar elements.

This document will compare these instruments through observation of the compound eyes of everyday insects. Further, an example will be given of SPM analysis methods operating at a level unobtainable with SEM. It goes without saying that the sample observation of insect compound eyes is akin to the observation and measurement of any number of materials.

1. Comparison of SPM and SEM Images

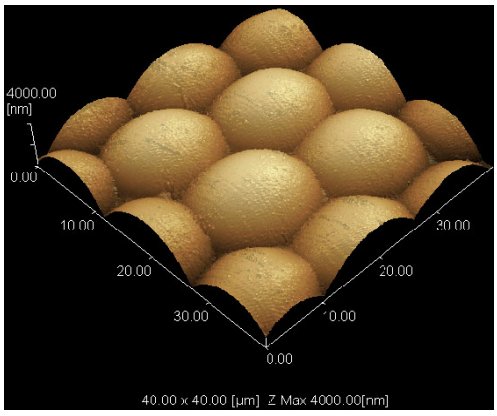


Fig.1 Image of the Compound Eye of an Ant (Mixed 3-Dimensional Image)

SPM images (Fig.1)

Compound eye of an ant, shown as a 3D image

A 3D image is created based on accurately measured values for height at various points, allowing the irregularities of the surface of the compound eye to be realistically observed. As the color of the sample is not observable with SPM, pseudo-colors are used. Colors can be added and applied in accordance with sample information. Some 3D images are a mix of processing based on height and the addition of shading from lighting effects. In comparison with the SEM image, the SPM image offers the flexibility of re-processing from the saved image, and is also well-suited to subsequent evaluation.

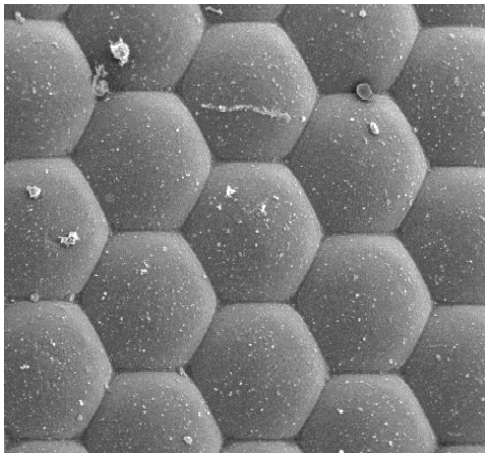


Fig.2 Image of Compound Eye of a Fly via SEM

SEM images (Fig.2)

This is an image with edge effects, a feature of SEM images. The SEM image contrast conveys 2D information, and is based not on height but on the quantity of signal (secondary electrons) produced. Accordingly, height data cannot be read, but the compound eye is observed sharply.

The SEM image is limited to processing from the saved image obtained. For example, separate images must be saved when samples are inclined and for every other condition during exposure.

In comparison with SPM, this method is effective for broad fields of view and for samples with large irregularities.

2. Cross-Sectional Observation and Analysis of Height via SPM

The shape of the surface of the compound eye is analyzed using the 3D information in the SPM image. Fig. 3 is a topographical image (*). The cross-section of the analysis line A-B in the image is shown in Fig. 4. The longitudinal scale of the cross-section is shown enhanced about 3 times. From the image, the height of one section of the compound eye, shown by the red line, can be read as 2.91 micrometer. Also, from the green line, the width of one section of the compound eye is measured at 16.0 micrometer.

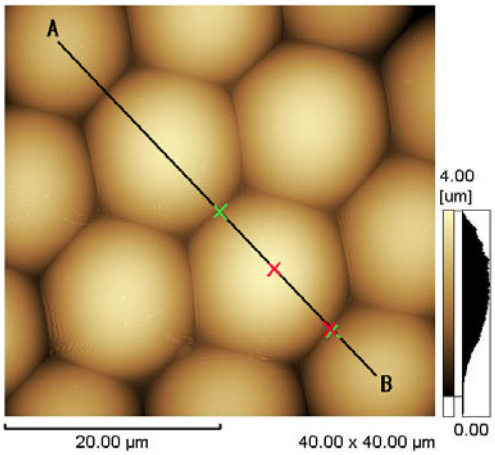
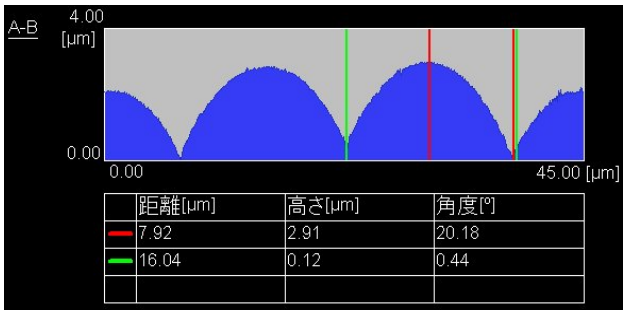


Fig.3 Topographical Image and Analysis Line A-B



Distance (micrometer), Height (micrometer), Angle (°)

Fig.4 Cross-Sectional Image and Height Analysis

Topographical image (*) Height and the distribution of height can be analyzed from the color bars and histogram shown to the right of the image.

3. Analysis of the Roughness of Compound Eyes

With SPM, the roughness of the compound eye has been analyzed using statistical methods. Many of the objectives for using SPM involve measurement of roughness. In comparison to roughness measures with the stylus method, accurate measurements can be obtained across a scale ranging from linear and surface micro-roughness all the way to nano-roughness, an SPM specialty. The SPM 3D signal is automatically analyzed. However, frequently used values such as "average roughness" and "maximum roughness" are shown as in Fig. 5.

Length X Y: Measurement area
Ra: Arithmetic average roughness
Rz: Maximum roughness (height)
Rzjis: JIS + point average roughness
Rq: RMS roughness
Rp: Maximum peak height
Rv: Maximum trough depth

Rp + Rv = Rz relationship

Note: Analysis of the roughness of the compound eye of an ant is not common.

LengthX	40.000[µm]
LengthY	40.000[µm]
Area	1600.000[µm²]
Ra	662.704[nm]
Rz	4.403[µm]
Rzjis	2.178[µm]
Rq	795.501[nm]
Rp	1.708[µm]
Rv	2.695[µm]

Fig.5 Roughness Data for Compound Eye of an Ant

4. Particle Analysis via SPM

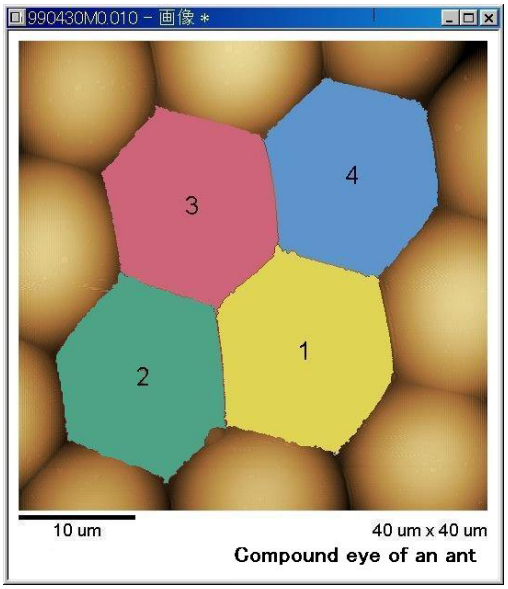


Fig.6 Image Extraction via Particle Analysis Software

SPM particle analysis software provides instantaneous statistical analysis of target factors chosen from approximately 30 types of characteristic quantities, based on contour extraction of the image using height data and area from the 3D image information. Further, these characteristic quantities can be freely tabulated and displayed as graphs. In this document, the following 4 types of characteristic quantities are selected for the analysis.

(1) Average radius
(2) Maximum Z value
(3) Surface area
(4) Volume

In the example in Fig. 6, a total of 14 particles (eyes) are extracted using contour extraction. Those deemed incomplete particles are automatically eliminated, and the remaining complete particles from 1 to 4 are then extracted. More than 1,000 particles can be processed at high speed, meaning that the equipment is even compatible with analysis of extremely small nano-particles.

Fig. 7 shows four characteristic quantities, corresponding to numbers 1 through 4 in Fig. 6.
From these results, it is evident that the first particle has an average radius of 7.86 micrometer, meaning that the diameter is approximately 15.7 micrometer.
The height is 2.95 micrometer. As this is approximately 1/5 the diameter, the eye cannot be said to protrude.

Number	Average Radium [μm]	Maximum Z value [μm]	Surface area [μm2]	Volume [μm3]
1	7.856	2.948	262.2	315.8
2	7.456	2.871	256.1	257.2
3	7.656	2.876	242.8	295.0
4	7.578	2.765	235.7	276.3

Fig. 7 Particle Analysis Results Sheet

As shown above, SPM, which embraces the 3D world, offers analyses that are impossible with 2D SEM. Not only this, the technology shows further promise, including the possibility of free utilization even with images subsequent to acquisition.