Scanning tip evaluation using a needle-shape artifact

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KEYWORDS : nanometrology, scanning probe microscope, tip shape, decomvolution, uncertainty

A tip shape evaluation methods using a needle shape artifact have been studied. With an improvement of tip approaching technique, a tip damage caused by tip-sample clashing was dramatically decreased to less than 1 nm. The tip shape data evaluated using the needle artifacts were used to correct AFM images with an uncertainty less than 40 nm.

Manuscript received: January XX, 2011 / Accepted: January XX, 2011

1. Introduction (Times New Roman 10pt)

Scanning probe microscopes, especially an atomic force microscope (AFM), are applied to measure a surface geometry with nanometre resolution by scanning tips. There are two kinds of tasks to overcome for precision measurement using the scanning tips. One is a repeatability of measurements. By comparison with other scanning probes, such as a focused electron beam and a laser beam, the scanning tips are easily damaged so that the measurement data changes depending on the apex shape of the tip employed to each measurement. The other is a quantitative reliability of measurement data. The measurement data are overlapped between the tip shape and the surface geometry.

For precision measurements of surface profiles, we should evaluate the tip shapes before and after the measurements with less damage to the tip shape, and correct the AFM measurement data using the tip shape data. In this presentation, we report a measurement method with less tip damage and a tip shape evaluation using a needle structure, and also an application to a calibration service of linewidth measurements of photomasks.

2. Experimental (Times New Roman 10pt)

A conventional AFM (L-trace, SII NanoTechnology Inc.) was employed to measure the needle shape artifact (TGT1, NT-MDT Inc.) in air. The scanning mode was SIS mode, in which the tip moves up to vertical direction by several 10 nm to avoid the tip damage during the horizontal movements at each of data acquisition positions. The tips of conventional cantilever designed for AC mode, typical tip radius of less than 10 nm and resonant frequency of ~300 kHz, were used.

3. Results (Times New Roman 10pt)

An illustration of a scanning tip on a needle artifact is shown in fig. 1(a). A typical corn angle of the tips employed was 10 - 30 degree, and a corn angle of the artifacts was 20 or 50 degree. An AFM image of a wider scanning area of 10μm is shown in fig. 1(b). The needle artifacts were fabricated in area of 2 mm square on a chip of Si wafer, as shown in the inset image.

A uniformity of the needle artifacts was inspected by sampling 3 x 3 grid positions in the area of 2 mm square. In fig.2, the dependence of the needle shapes on the different locations was shown. There were different tendency before and after an improvement of a tip-sample approaching technique.

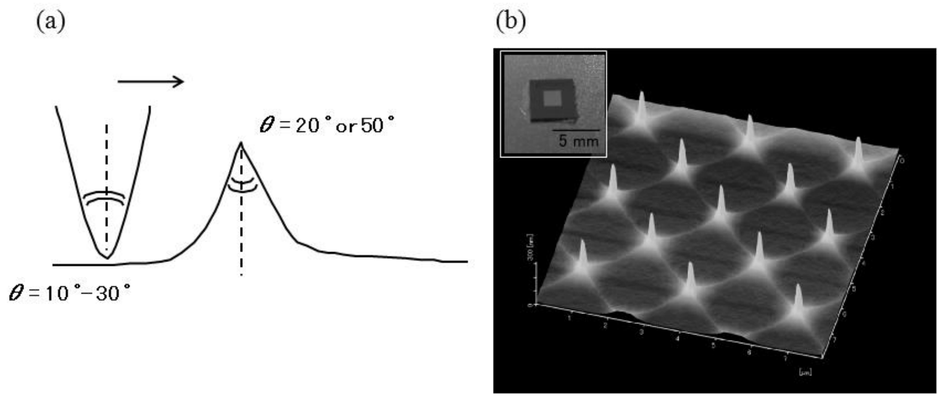

Fig. 1 An illustration of a scanning tip on a needle artifact (a), and an AFM image of the artifacts with a scanning area of 8 µm (b).

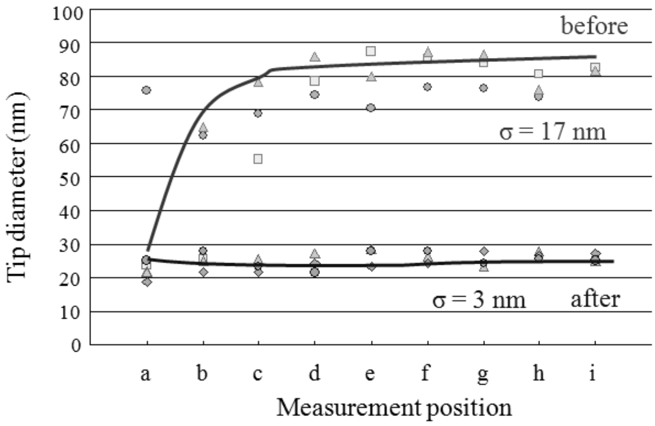

Fig. 2 A tip diameter dependence on measurement positions before and after a improvement of tip-sample approaching technique. The vertical axis is a diameter of a fitted circle to a cross-section of the needle image at a height-threshold of 10 nm from the apex.

4. Discussion (Times New Roman 10pt)

An image resolution of AFM depends on an apex shape of scanning tips. The tip shape easily changes not only for a wear, but also for a clash under an overload condition. The tip-sample clashing for approaching tips to measurement positions became a big problem to evaluate the uniformity of the needle artifacts. Therefore we improved the approaching technique, so that the needle shape evaluation was performed with less damage of the tips. The uniformity of the artifact was enough as a test sample of tip shape. Then, using the needle shape data, AFM image can be corrected with a small uncertainty through a deconvolution process. The technique has been applied to a calibration service of photomask linewidth measurement in NMIJ, which was developed recently[1].

5. Conclusions (Times New Roman 10pt)

Using careful tip approach techniques on sample surface before tip scanning, the tip damage caused by tip-sample crashing was dramatically decreased. The measurement repeatability of less than 1 nm was performed for the needle structure. Using the tip shape data, AFM data were corrected with uncertainty less than 40 nm for line structures. We just started the calibration service of linewidth mesurment of photomasks with an uncertainty of 60 nm for calibration range of 0.5 µm to 10 µm.

REFERENCES

1. To be presented at SPIE/Scanning 2011.