QUANTITATIVE ANALYSIS OF TOPOGRAPHIC EFFECTS ON CONDUCTIVE SURFACES

in the PHI *nanoTOF*

INTRODUCTION

Time-of-flight secondary ion mass spectrometry (TOF-SIMS) is used to image the distribution of elements and molecules on the surface of a wide variety of materials. Many samples of technological interest have a high degree of topography. These samples may be in the form of wires, particles, tubes, spheres, or other more complex shapes. The objective of TOF-SIMS imaging is to determine the 2-dimensional concentration variation of elements and molecules on surfaces. This objective is complicated on rough or curved surfaces due to topographic contrast.

In a study published by Lee and colleagues at the National Physical Laboratory (NPL), the topographic effects in TOF-SIMS images were quantified using a model system of gold wires ranging from 33 µm to 125 µm in diameter [1]. This detailed study offers a basis for quantitatively evaluating the topographical effects for a TOF-SIMS instrument on conducting samples. The study by Lee et. al. was done with an ION-TOF TOF-SIMS IV instrument. In this study, three different gold wire diameters were imaged using the PHI *nanoTOF*. The images were processed using the same methodology so that a direct comparison can be made.

EXPERIMENTAL

Gold wires were purchased from the Goodfellow Corporation with diameters of 25 µm, 60 µm, and 125 µm. The wires were mounted without further cleaning on a silicon wafer substrate and held in place with silver paint. All data was acquired with a PHI *nanoTOF* using a 30 kV Au_1^+ primary ion beam operated in the bunched mode.

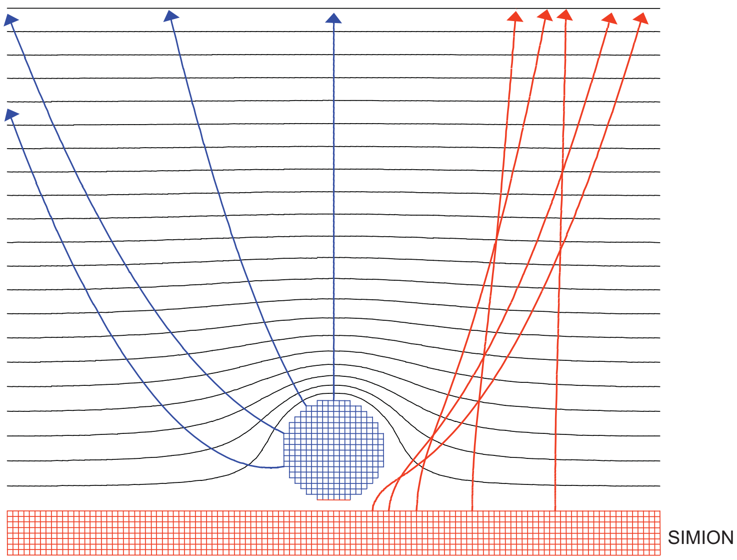

Figure 1: Simulation of the extraction field distortion from a 60 µm conducting wire on a flat conducting substrate. Arrows indicate the flight path of secondary ions from various locations on the wire (blue) and the substrate (red).

The LMIG column is at an angle of 40° from the spectrometer optical axis with a bunched beam diameter of approximately 1 μm in diameter. The extraction gap in the *nanoTOF* was 2 mm with an extraction potential of 3 kV.

RESULTS AND DISCUSSION

Topographic contrast is more severe on conducting samples than on insulating samples because, in the case of conductors, the equipotential field lines in the extraction region follow the topography of the sample surface (Figure 1). This causes secondary ions to be pulled off-axis during acceleration in the extraction region. The secondary ion flight paths shown in Figure 1 were calculated using SIMION for a 60 μm wire and an extraction field of 1.5V/μm. The trajectory of secondary ions from the side of the wire and from the substrate near the wire are altered by the distorted extraction field.

Using the NPL method [1], total ion images of the 125 μm gold wire are shown in Figure 2 using both a linear and log intensity scales. The

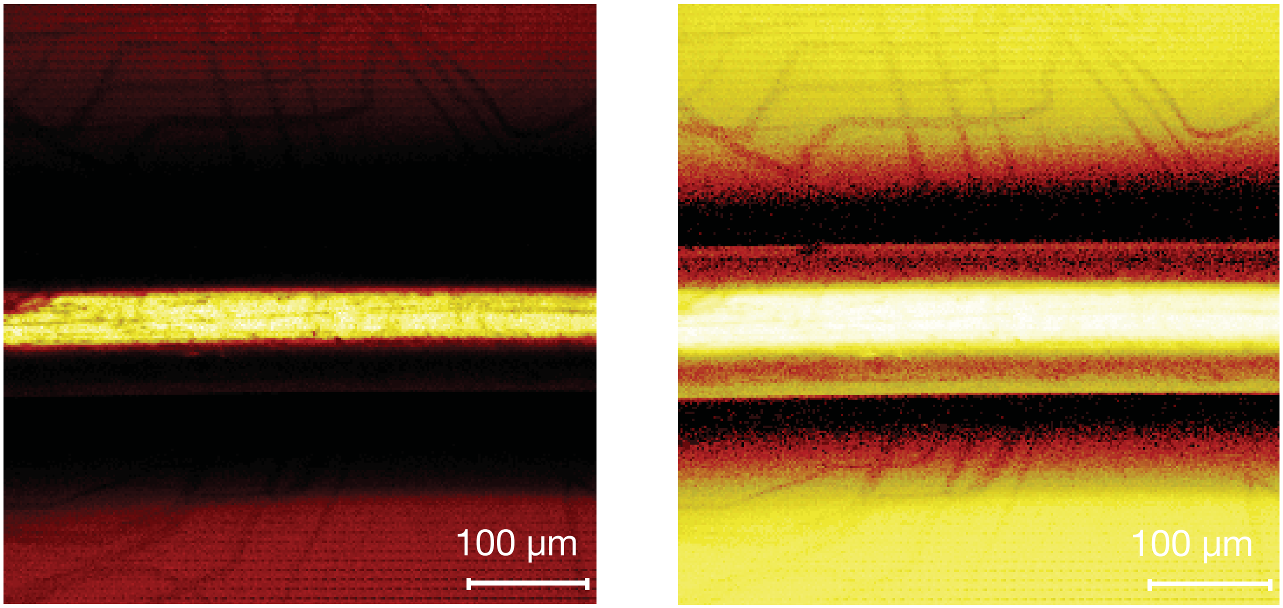

Figure 2. Total ion images of the 125 μm gold wire displayed with linear (left) and log (right) intensity scale. Field of view is 500 μm x 500 μm.

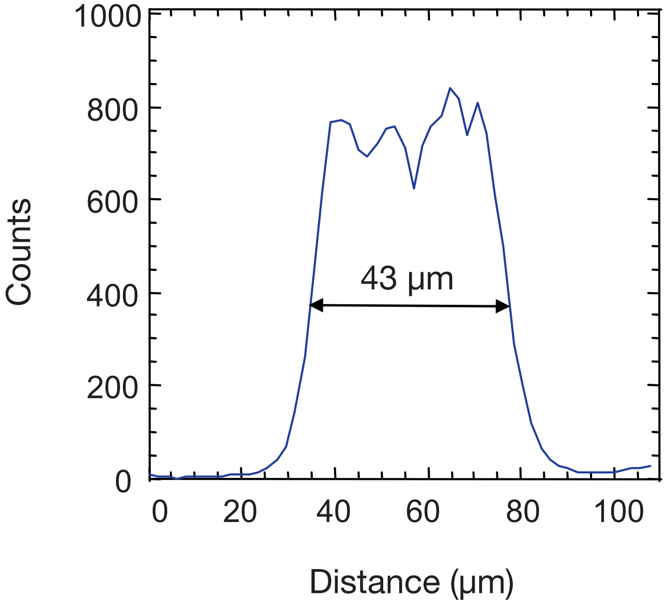

Figure 3. Line scan across the total ion image of the 125 μm gold wire. The double arrow horizontal line shows the FWHM, indicating that the viewable wire width is 43 μm.

observable width of the wire was measured to be 43 μm. This was determined quantitatively by plotting the total ion intensity line scan across the wire and measuring the distance of the FWHM (Figure 3). This same measurement was done for the other two wire diameters and the results are compared to the published results of Lee et al. in Figure 4. The results from the PHI *nanoTOF* indicate that the viewable wire width increases with increasing wire diameter and therefore has a wider angular acceptance than the instrument used in the NPL study [1] where the observable width remains constant. The log scale image in Figure 2 shows that the signal from the substrate has a narrow band on each side of the wire where the secondary ions were not detected due to distortion of the extraction field. A figure of merit called the "shadow size" was defined by Lee et al. and was determined by measuring the distance between the points on each side of the wire where the substrate intensity increases to 10% of the maximum substrate intensity at a large distance from the wire. In this study, the shadow size for the 125 μm wire was measured to be 245 μm. Since

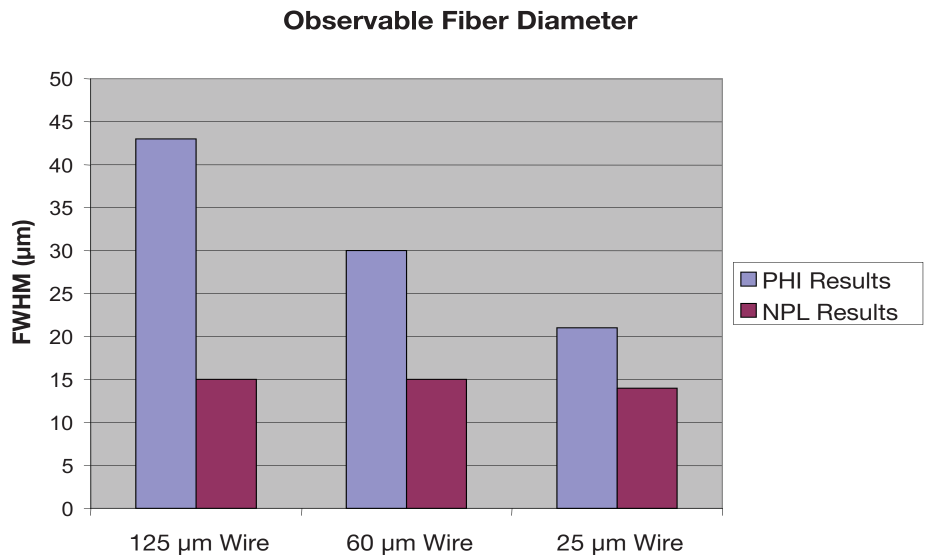

Figure 4. Plot of viewable wire width as a function of gold wire diameter for the nanoTOF (blue) compared to the published results of Lee et al. (red) [1]. The smallest wire was 25 μm in this study.

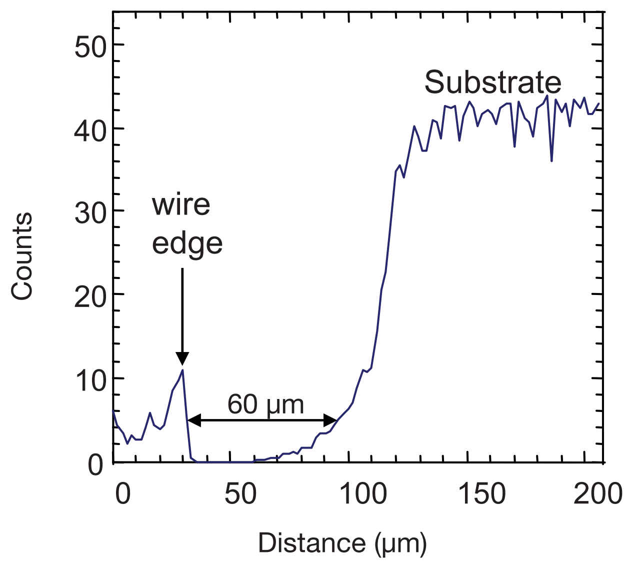

Figure 5. Line scan from the total ion image of the 125 μm diameter gold wire. The double arrow horizontal line shows the shadow on one side of the wire is approximately 60 μm.

125 μm of this distance is the wire itself, the actual shadow on each side of the wire was approximately 60 μm. An example of a line scan used to make this measurement on each side of the wire is shown in Figure 5. This same measurement was made for the other three wire diameters and the results are compared to the published results of Lee et al. in Figure 6. For the smallest wire diameter of 25 μm, the shadow size was zero because the substrate signal did not decrease to 10% of the maximum value next to the wire.

The extraction voltage was 3kV for all the results presented here. In the study by Lee et al., it was reported that the secondary ion solid angle of collection could be increased by 28% by decreasing the extraction voltage from 2 kV to 500 V. However, as they note, this improvement is at the expense of lower mass resolution, analyzer transmission, and primary ion beam repetition rate.

CONCLUSIONS

The protocol published by Lee et al. offers a quantitative way to evaluate the topographic effects of a TOF-SIMS instrument. This protocol was followed in this study in order to compare the solid angle of collection of the PHI *nanoTOF* to published results. The viewable wire diameter was larger and the substrate shadow was smaller in this study for all three wire diameters, indicating the PHI *nanoTOF* has a larger angular acceptance which results in less topographic effects.

REFERENCES

1. J.L.S. Lee, I.S. Gilmore, I.W. Fletcher, M.P. Seah, "Topography and Field Effects in the Quantitative Analysis of Conductive Surfaces Using TOF-SIMS", Applied Surface Science, 255 (2008) 1560-1563.

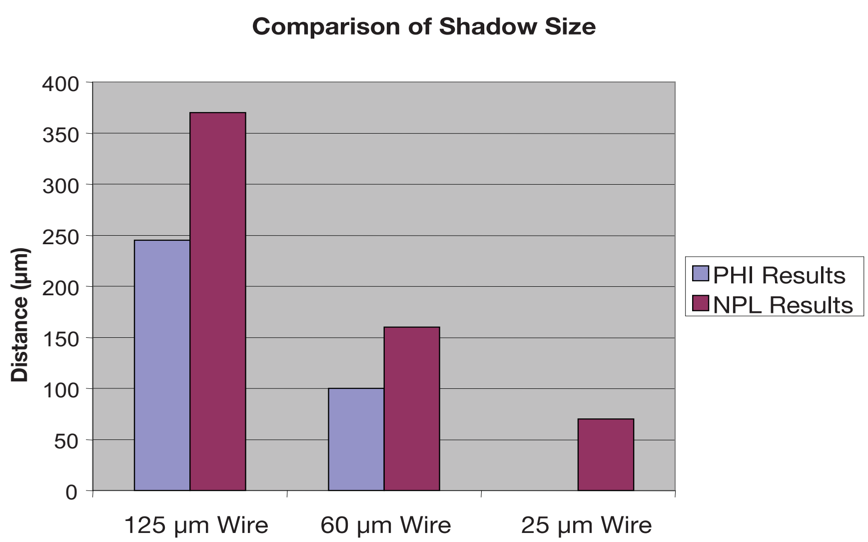

Figure 6. Comparison of the shadow size of the substrate signal measured for the different gold wire diameters. The smallest wire was 25 μm in this study.

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