Optimized Depth Resolution with Low Voltage Sputtering and Zalar Rotation

Auger depth profiles are often used to determine both the composition and thickness of thin film structures. Obtaining such profiles with high depth resolution provides the most accurate depth information and the highest confidence in subsequent data interpretation. High depth resolution is especially important for identifying interfacial composition and contamination, and for resolving thin buried layers.

This note illustrates the improvement in depth resolution that is obtained when utilizing optimized sputter conditions. Three parameters can be used to improve the depth resolution: lower the impact energy of the sputter ions, rotate the sample during sputtering (Zalar™ Depth Profiling), and orient the ion beam at grazing incidence to the sample surface. The PHI 680 Scanning Auger Nanoprobe provides the user with easy implementation of all three methods to improve depth resolution.

Sputter depth profiles were obtained on a multilayer, magnetorestrictive, nanoscale test structure. The sample is comprised of 81 alternating layers of $Fe_{0.5}Co_{0.5}$ and $Fe_{0.5}Co_{0.25}Tb_{0.25}$. The nominal layer thickness' are 9 nm and 7 nm, respectively. Depth profiles were obtained using a 2 keV Ar^+ beam with no Zalar rotation, and using a 250 eV Ar^+ beam with Zalar rotation.

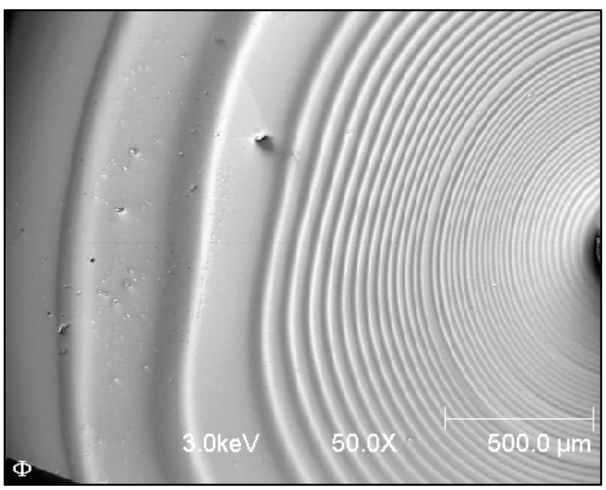


Figure 1. SEM image of sputter crater.

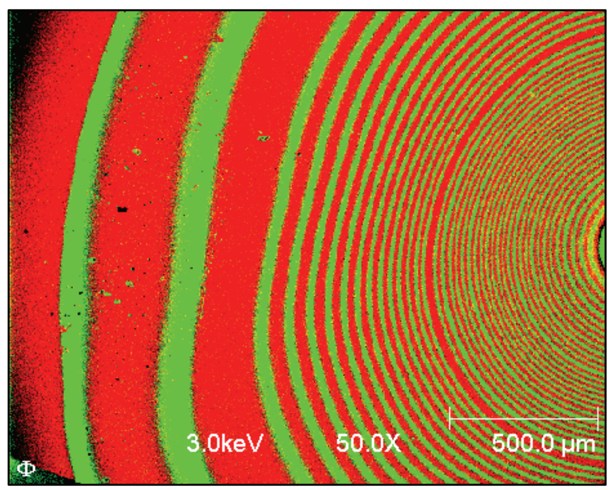


Figure 2. Auger maps: Red = Co and Green = Tb.

Figure 1 shows the sputter crater after the 250 eV Ar^+, Zalar depth profile. The image shows one half of the crater, from the free surface of the sample to the center of the crater. This represents a shallow-angle, tapered cross-section through the multilayer film structure. Figure 2 shows a color overlay of the Co and Tb Auger maps obtained over the same area. Careful counting shows that all 81 layers are clearly evident.

Figure 3 shows the sputter depth profile obtained using optimized conditions. The ion beam is located at a grazing angle of 75 degrees from the sample normal (15 degree incidence to the sample surface.) The ion impact energy was set to 250 eV and Compucentric Zalar rotation was invoked. Only the normalized Co and Tb profiles are shown for clarity. Even though the difference in Co and Tb composition between the alternating layers is only 25%, all 81 layers are clearly resolved with high depth resolution throughout the full thickness of the sample. The zero level for Tb, and the maximum level for Co, in the $Fe_{0.5}Co_{0.5}$ layers changes by less than 3% from the surface to the deepest layers.

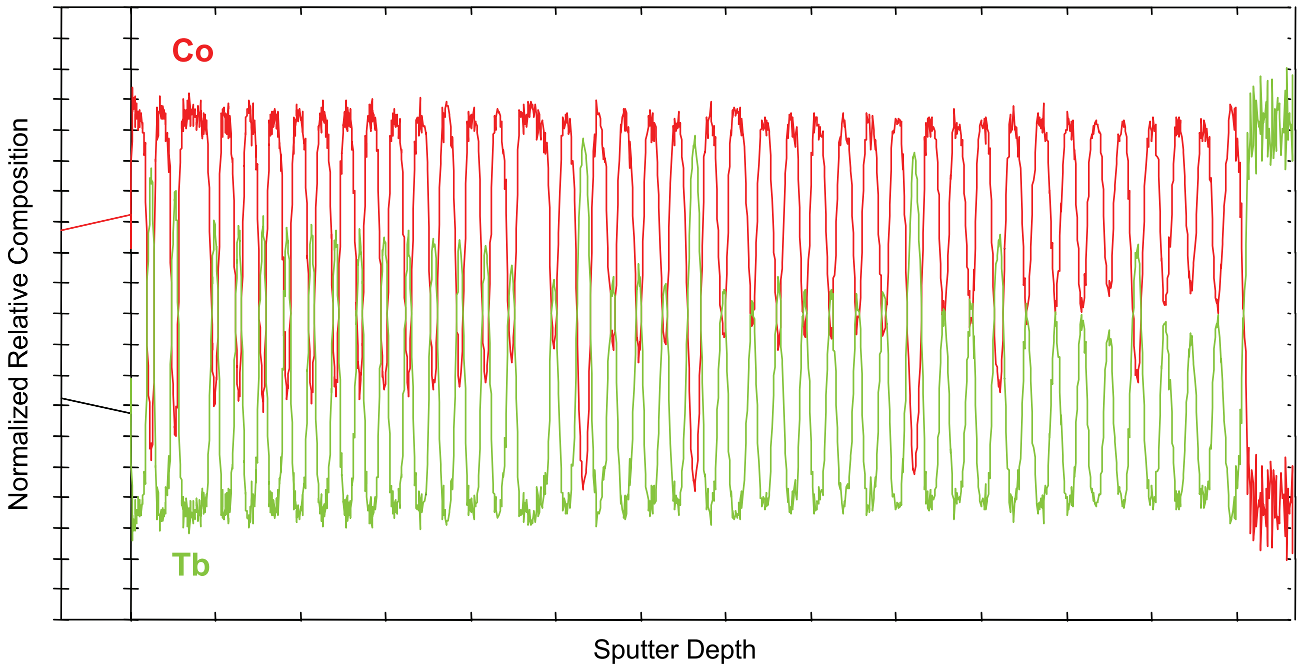


Figure 3. 250 eV ion beam energy with Zalar Rotation

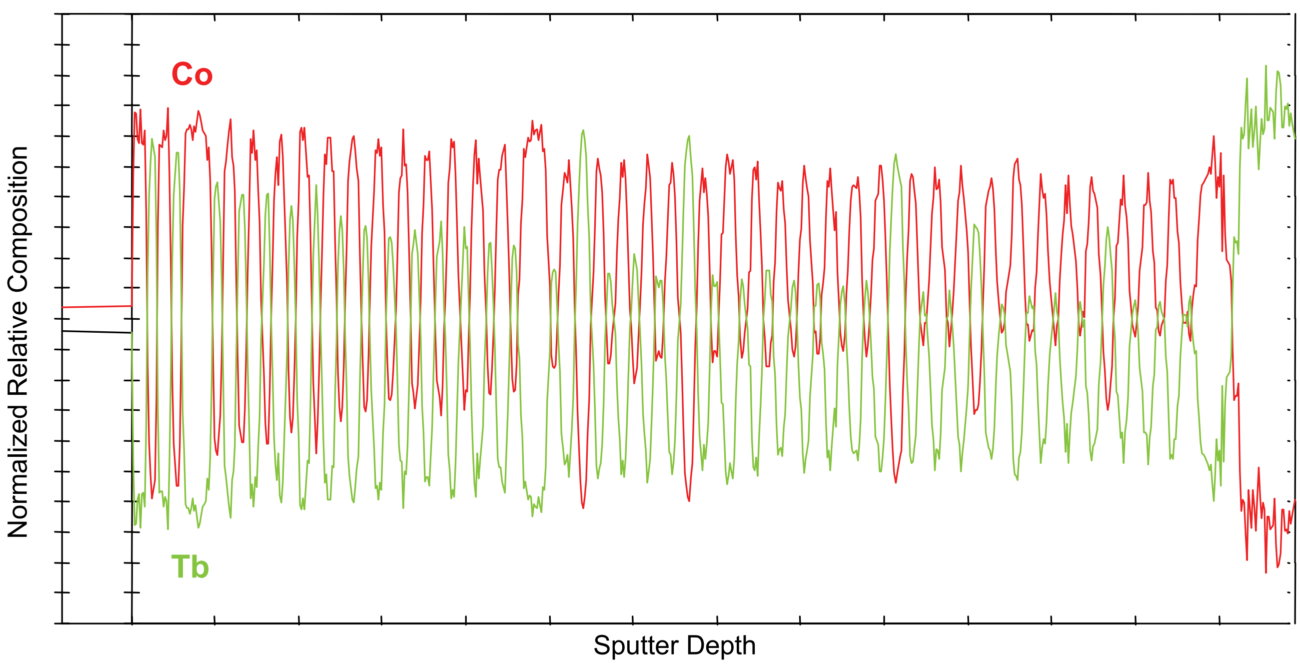


Figure 4. 2.0 kV ion beam energy without Zalar rotation.

A non-optimized, sputter depth profile was collected using typical parameters that are available with most modern Auger systems. The ion beam was kept at a grazing angle of approximately 75 degrees from the sample normal. The ion impact energy was set at 2 keV and no sample rotation was used. The results of this profile are shown in Figure 4. While all 81 layers are evident in the profile, the depth resolution is severely degraded compared to the previous profile. The apparent Tb intensity in the $Fe_{0.5}Co_{0.5}$ layers, which have no Tb, increases by more than 16% from the surface to the deep layers, with a corresponding decrease observed in the maximum Co intensity.

Several methods exist to improve the accuracy of the depth information in Auger depth profiles and provide increased confidence in subsequent data interpretation, as previously described. Three general “rules of thumb” can be followed to improve the interfacial resolution of Auger thin film depth profiles:

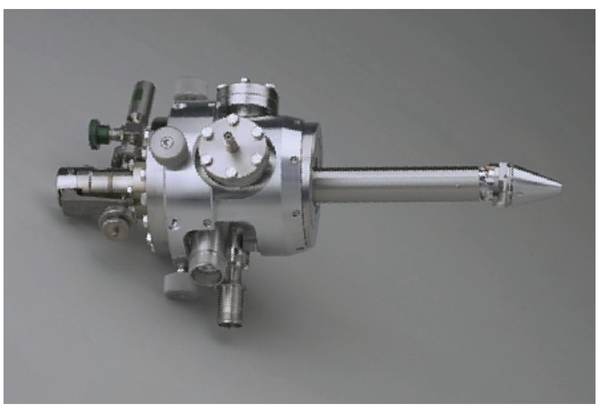
- Lower the impact energy of the ion sputter beam
- Orient the ion beam at grazing incidence to the sample surface
- Rotate the sample while ion etching (Zalar™ Depth Profiling)

The PHI 680 Scanning Auger Nanoprobe provides the user with easy implementation of all three methods to improve interfacial resolution.

First, the 680 is equipped with the PHI 06-350 ion gun and the 11-066 ion gun control. The ion gun can operate with a high accelerating voltage near the ionization chamber for the generation of high ion beam currents and it utilizes a beam retarding field near the objective lens to lower the ion impact energy. As a result the ion gun can deliver high ion currents and current densities at low ion impact energies (e.g., sputter rates of up to 50 Å/min at 500 eV impact energy).

Second, the versatile Model 15-680 specimen stage tilts from 0 to 60 degrees allowing the user to select ion impact angles of 15 to 75 degrees from the sample surface normal.

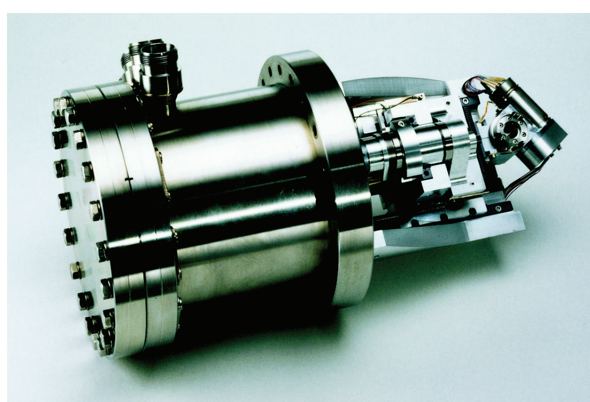
Third, Compucentric Zalar rotation control is a standard feature of the 15-680 specimen stage and the *PC-ACCESS™* system software that allows a selected analytical area to stay centered in the ion sputter beam while it is being rotated. This capability makes Zalar rotation available not only at the center of the sample mount but in any position within ±1 cm of the center of the sample mount.



PHI 06-350 ion gun.

The PHI 06-350 ion gun and associated 11-066 ion gun control offers extensive analytical capability and flexibility. This inert gas ion gun offers beam voltages from 0-5 kV and can also be operated as a floating column ion gun with high sputter currents at impact energies below 250 eV. The ion column has a 5° bend to eliminate neutrals. The gun is fully digitally controlled and offers stored user settings for the ultimate in experimental reproducibility.

The PHI15-680 specimen stage provides ±25 mm of travel in X and Y, 20 mm of Z travel and tilt of 0-60°, this stage accepts the full rage of standard PHI sample holders. Rotation is a continuous 360°. All motions are via internal UHV drive motors. The stage is digitally controlled and offers stored user settings. Combined with the AutoCom feature in PHI *PC-ACCESS* software the user can program multiple analysis positions with individually tailored analytical sequences for unattended analysis. Compucentric Zalar™ rotation is featured to minimize ion sputter artifacts.



PHI 15-680 specimen stage.

Acknowledgement: Dr. Christel Adelhelm and Mr. Eberhard Nold for their cooperation in this work and for providing the thin film samples. Both are affiliated with the Institut fur Materialforschung I, Forschungszentrum Karlsruhe, Germany.

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