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Analysis of Thin Film Specimens Using ToF-SIMS Wedge Protocol, A Comparison with Depth Profiling

Vincent Smentkowski[1], Shubhodeep Goswami[2], Felix Kollmer[3], Julia Zakel[4], Henrik Arlinghaus[4] and Derk Rading[4]

[1]General Electric - Research, Niskayuna, New York, United States, [2]GE Reserach, United States, [3]IonTof GmbH, Germany, [4]IonTof GmbH, United States

Depth profiling (1D or 3D) is often used to determine the depth distribution of species in thin films [1, 2]. An advantage of ToF-SIMS depth profiling is a full mass spectrum is saved at every volume element enabling 3D analysis of unexpected species; the analyst does not need to select the species at the start of the measurement. A disadvantage of ToF-SIMS depth profiling is the analyst needs to determine if they want to optimize the erosion and detection protocol for the collection of either the positive or negative ion fraction. MCs+ analysis [3, 4], where the region of interest is eroded using a Cs+ ion beam and a Bi+ cluster ion beam is used to perform positive ion depth profile analysis has been reported; MCs+ analysis enables the collection of both positive ion and negative ion species in one depth profile measurement. Disadvantages of MCs+ analysis include data complexity [3] and for optimal performance, Xe/Cs co-sputtering is required [5]. In 2011, Mao et.al. reported wedge sample preparation for ToF-SIMS analysis of thin layers using a home-built instrument [6]; in 2018 IonTof added wedge preparation into their commercial instrument.

Impurity detection, quantification and baseline monitoring with high throughput ToF-SIMS is needed to improve quality and consistency of both the film deposition processes and equipment. A reliable analytical protocol, using wedge preparation, that enables the detection of a wide range of both positive and negative ions, on a single section of a wafer sample, translates to less equipment downtime as fewer monitoring wafers need to be run on the fab production line. It is important to note that during failure analysis of low-yielding devices, there is often only a limited number of samples (with limited accessible surface area within the de-processed devices) that is available for destructive tests (including for ToF-SIMS). It is also imperative that a fast feedback of results from analytical tests is available to the fab production line. In these scenarios, the wedge protocol has a number of benefits over depth profiling.

The layer structure of the sample analyzed here is: Au (50 nm)/TiW (150 nm)/SiO2 (500 nm) on a Si substrate. The ToF-SIMS analysis reported here were performed on an TOF.SIMS 5 instrument from IONTOF GmbH described in detail elsewhere [7]. The positive ion depth profile traces shown in Figure 1, cleanly identify the layers; unexpected impurities will be shown in the presentation.

After the depth profile measurement was performed, the sample was moved a few mm and a wedge cut was performed using 2kV O2+ ions (600 nA DC current). The wedge size was 400 x 400 microns and the dwell time was 50 ms. The total time to generate the wedge was less than 17 minutes. After the wedge preparation has been performed, the analyst can perform any sequence of analysis they desire; positive polarity imaging, negative polarity imaging, imaging using different analysis conditions; all from the same region of the sample. Figure 2 shows high mass resolution (low lateral resolution) positive ion image analysis of the same species shown in the depth profile (Figure 1). The columns on the right side of the images show the areal line scan traces constructed from the region shown in the images.

In our presentation, we will also show negative ion images collected from the same wedge cut shown in Figure 2 and highlight the benefits of wedge preparation.

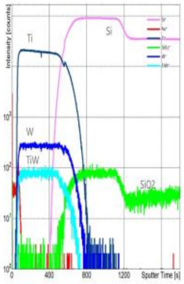

Figure 1. Figure 1. Positive ion depth profile showing select species; all three layers are easily detected.

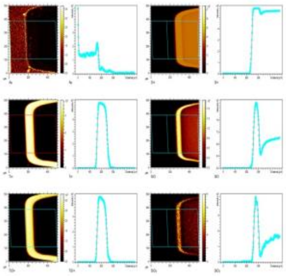

Figure 2. Figure 2. Positive ion images of a 500 micron area containing the wedge cut. The columns on the right side show the areal line scan trace constructed from the parallelogram shown in the images.

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