

Texture Inhomogeneity in Tantalum Sputter Targets

Introduction

Sputter deposition is a process for depositing thin films onto a substrate. It is used extensively for thin film deposition. Sputtering is used in the microelectronics industry to deposit thin films of various materials, typically onto silicon wafers. Other examples of sputtering applications include the deposition of antireflective coatings on glass, the fabrication of DVDs, CDs and hard disks, making photovoltaic solar cells, and coating tool bits with hard materials, such as titanium nitride.

In this technical note, we will discuss how Orientation Imaging Microscopy (OIM™) is an ideal tool for characterizing both the homogeneity of texture and microstructural inhomogeneities in the target material.

Sputter Deposition

As shown schematically in Figure 1, the process of sputter deposition is accomplished by bombarding a target of the desired deposition material with ions. The incident ions initiate collision cascades within the target. When the cascades reach the target surface with enough energy to overcome the surface binding energy, an atom can be ejected. A schematic of a sputter chamber is shown in Figure 2. An electric field ionizes the incoming gas (typically argon). The positive ions bombard the target (cathode) and the sputtered atoms condense on the substrate (anode). The substrate may be heated to improve bonding.

The sputter yield (i.e. the average number of atoms ejected from the target per incident ion) depends on several parameters including the ion incident angle with respect to the surface, the energy of the ion, the relative masses of the ion and target atoms, and the surface binding energy of target atoms. While the relatively large number parameters affecting sputtering makes it a complex process, having so many control parameters provides a large degree of control over the growth and microstructure of the resulting film.

Anisotropy

For a crystalline target material, the orientation of the lattice with respect to the target surface impacts the sputter yield. In a polycrystalline sputter target, grains of differing orientation sputter at different rates. This can affect the uniformity of the deposited thin film. One critical control parameter is the homogeneity of the texture in the target material.

Figure 3 shows the anisotropy for sputtering yield in a copper single crystal (after Magnuson & Carlston, 1963). The general trend holds for all face-centered cubic materials, namely: $S(111) > S(100) > S(110)$.

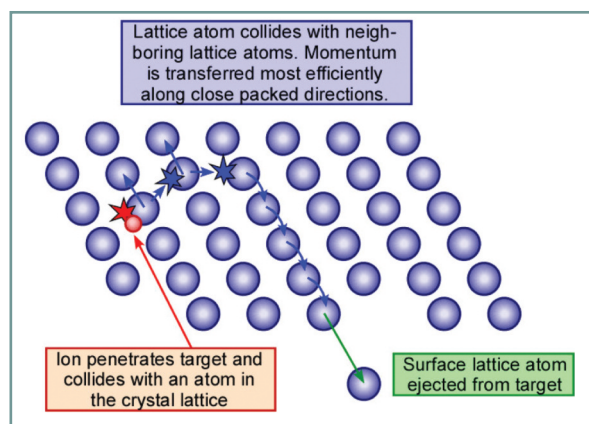


Figure 1. Schematic of solid oxide fuel cell.

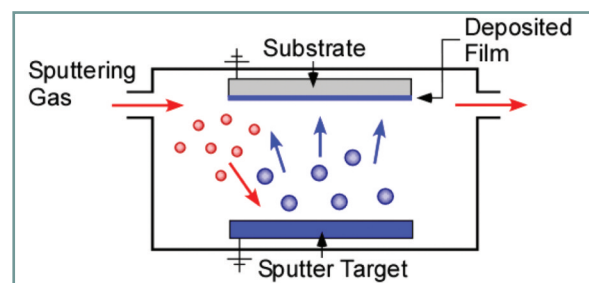


Figure 2. Schematic of a sputtering chamber.

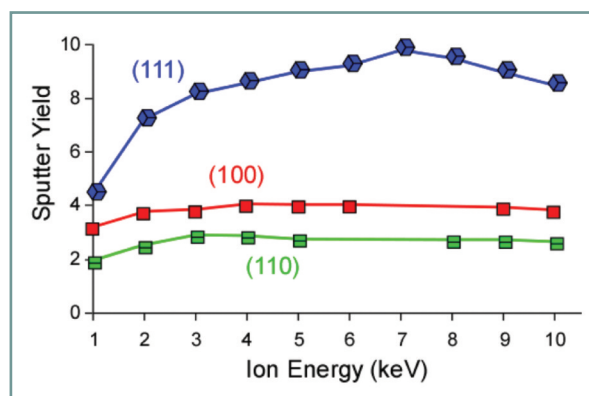


Figure 3. Sputter yield in a copper single crystal as a function of crystallographic direction.

The effect of this anisotropy is evident in Figure 4, which shows a portion of a tantalum sputter target after use. The texture in the dark areas, as measured by OIM™, is primarily a cube texture, i.e. (100)[001], whereas the texture in the lighter areas is a moderate (111) type texture.

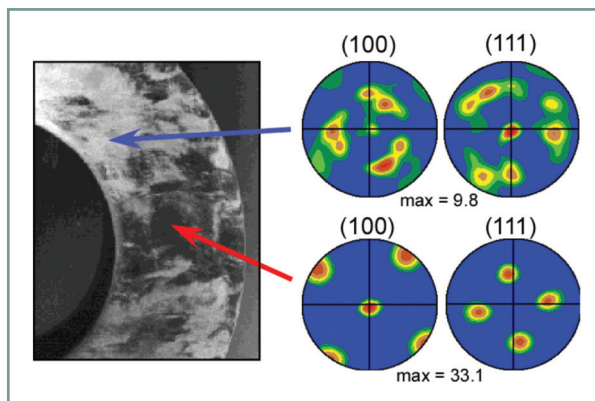


Figure 4. Sputtered surface of target and corresponding textures.

Texture Gradients

Figure 5 shows two microstructures, one well suited as a sputter target and the other with considerable texture banding, which is detrimental to sputtering performance. Various methods have been developed to quantitatively describe the homogeneity of texture in sputter targets. These methods are based on analysis of orientation measurements obtained by OIM™. These methods have generally focused on tantalum targets as texture homogeneity is a frequent problem in their fabrication.

Currently, a texture homogeneity standard is being developed by ASTM International for sputter targets. The standard is based on OIM™ measurements through the thickness of the sputtering target material. The standard focuses on tantalum but could be easily adapted to other sputter target materials.

ComboScan for Large Area Mapping

The spatial scale of the microstructural inhomogeneity present in sputter targets can be large relative to typical analytical areas of interest using scanning electron microscopy. To characterize these types of samples, an approach termed ComboScan has been implemented. With ComboScan, an area of interest and analytical magnification is first defined. This total area is then divided into multiple fields-of-view, the size of which are determined by the magnification used. The Scanning Electron Microscope (SEM) stage coordinates required for each field

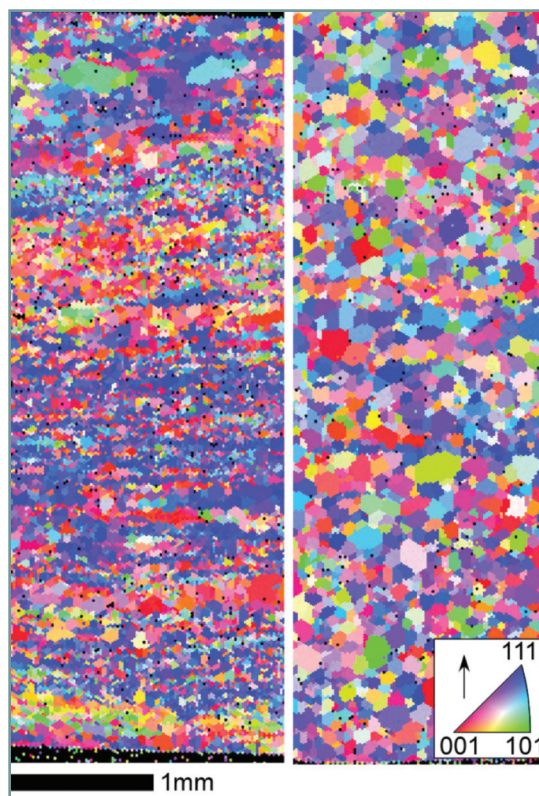


Figure 5. Orientation maps of undesirable (left) and desirable (right) target microstructures. The colors show the crystal direction aligned with the vertical direction.

are calculated. Each field is mapped using beam movements, while the stage position is changed between each field. The data acquired from all the measured fields is then stitched together into a single dataset for analysis and visualization. An acquisition wizard has steps that take users through the ComboScan process, which allows for easy analysis of large areas.

Conclusions

OIM™ is capable of quantifying through-thickness variations in texture in sputter targets. This allows the microstructural inhomogeneities to be correlated to sputtering performance. ComboScan allows users to easily analyze large areas of interest that are typical when dealing with the inhomogeneity present in sputter targets. These results highlight one of the real advantages of Electron Backscatter Diffraction (EBSD) over traditional X-ray pole figure measurements of texture. As EBSD is a spatially specific technique, it is ideal for measuring local variations in texture in polycrystalline materials.

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