Texture Inhomogeneity in Tantalum Sputter Targets

Adapted from a presentation by Chris Michaluk – *Cabot Perfomance Materials*

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.

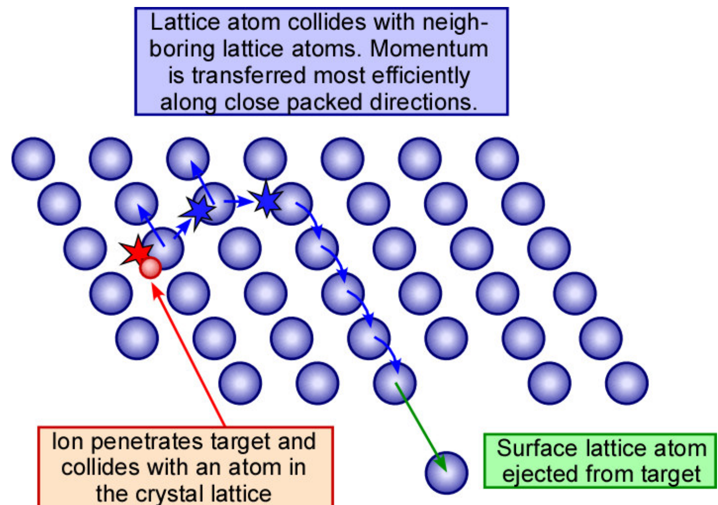

Figure 1 - Schematic of sputtering process.

As shown schematically in figure 1, the process 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.

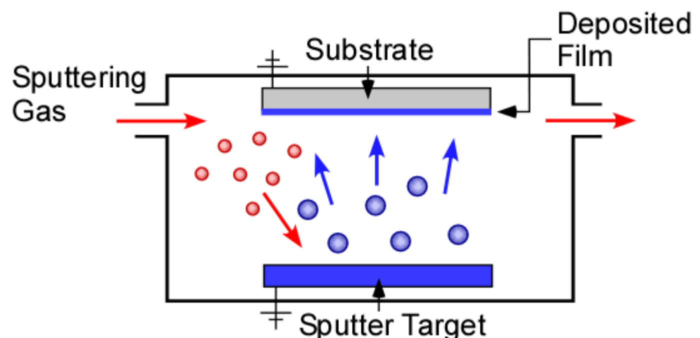

Figure 2 - Schematic of a sputtering chamber.

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. Thus, in a polycrystalline sputter target, grains of differing orientation sputter at different rates. This can affect the uniformity of the deposited thin film. Thus, one critical control parameter is the texture, or rather, homogeneity of the texture, in the target material. OIM is an ideal tool for characterizing the homogeneity of 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). The affect 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.

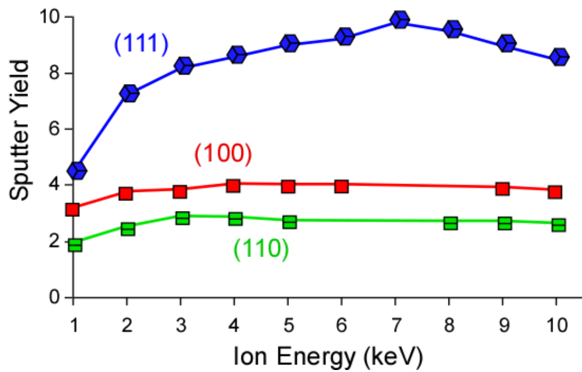

Figure 3 - Sputter yield in a copper single crystal as a function of crystallographic direction.

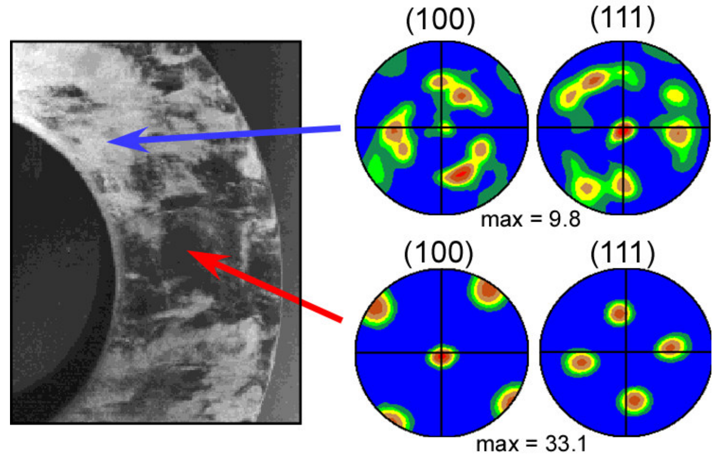

Figure 4 - Sputtered surface of target and corresponding textures.

Texture Gradients

Figure 5 shows two microstructures, one well suited for a sputter target and the other showing 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 the fabrication of tantalum sputter targets.

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 sputtering target material. The standard focuses on tantalum but could be easily adapted to other sputter target materials.

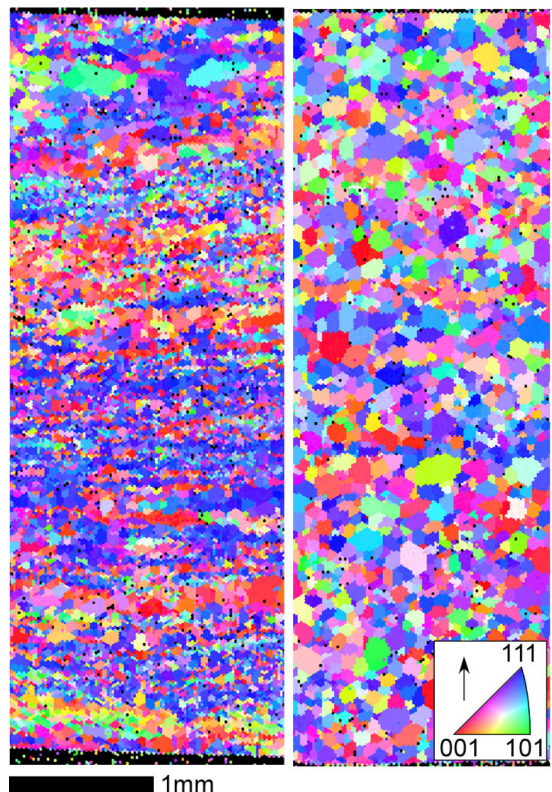

Figure 5 - Orientation maps of undesirable and desirable target microstructures. The colors show the crystal direction aligned with the vertical direction.

Conclusions

OIM is capable of quantifying through-thickness variations in texture in sputter targets. This allows the microstructural inhomgeneities to be correlated to sputtering performance. These results highlight one of the real advantages of 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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