Orientation Imaging Microscopy (OIM™) Analysis of Texture in a High Temperature Superconductor

Introduction

High temperature superconductors (HTSCs) are superconducting ceramics, generally containing copper oxide. Previously, it was assumed that superconductivity could only be achieved at temperatures less than 30 K. However, in 1987 the Nobel Prize was awarded to Karl Müller and Johannes Bednorz for the discovery of the first HTSC. These ceramic materials can achieve superconductivity at temperatures above the boiling point of liquid nitrogen (77 K). This makes them very attractive for a variety of practical superconductivity applications, such as in digital circuits, control magnets and power cables. The two most common types of HTSCs are YBCO ($YBa_2Cu_3O_7$) and BSSCO ($Bi_2Sr_2Ca_nCu_{n+1}O_{2n+6}$). The challenge with forming superconducting wires, tapes or films is that these materials are only superconductive along specific crystallographic directions. Thus the superconducting directions in the constituent crystals in a polycrystal must be closely aligned and the material must exhibit a strong texture in the superconducting directions. In order to overcome these obstacles, a variety of processes have been developed to maintain alignment of the superconducting crystal direction in the formation of materials for practical applications. OIM™ is an ideal tool for characterizing the alignment of the critical crystallographic planes at each step in the process to ensure alignment is achieved.

YBCO Tapes

One technique for creating a highly textured tape is to deposit YBCO on a strongly textured, oxide-buffered metal plate as shown schematically in Figure 1. The underlaying substrate must be strongly textured. This can be done using a technique called Rolling Assisted Biaxially Textured Substrate or RABiTS. The buffered layers are generally deposited by Physical Vapor Deposition (PVD) or chemical methods. There are two approaches for depositing the YBCO layer. (1) Pulsed Laser Deposition (PLD) in which the YBCO is formed in-situ as material is deposited. (2) Metalorganic deposition (MOD) where a precursor is deposited and then converted to YBCO after deposition. The two methods produce very different grain microstructures as shown in Figure 2. The PLD method forms a columnar grain structure, whereas the MOD method produces a laminar structure.

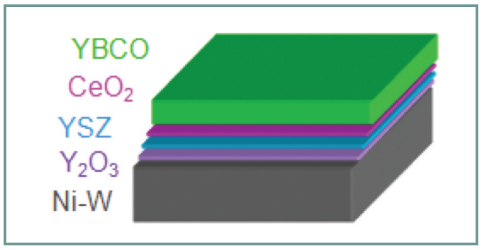

Figure 1. YBCO on an oxide buffered tape.

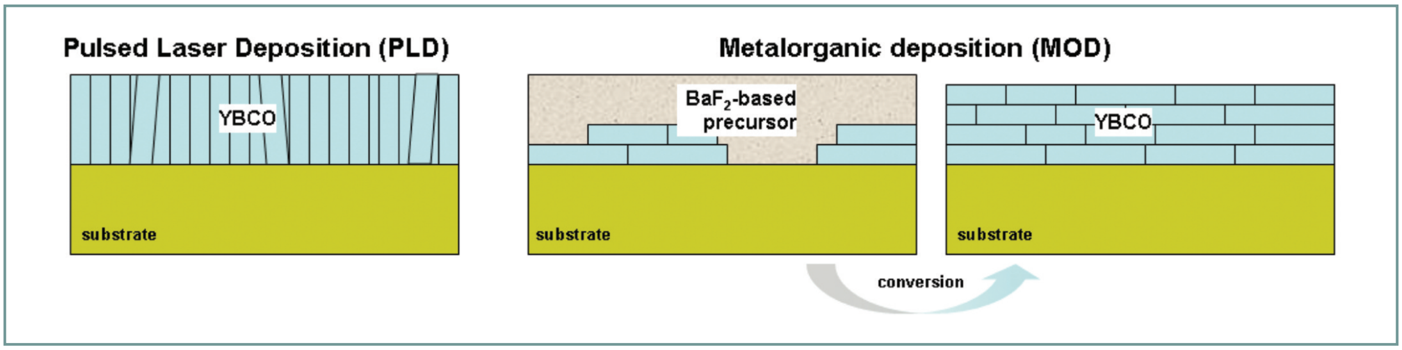

Figure 2. Schematic of grain structures produced by PLD and MOD.

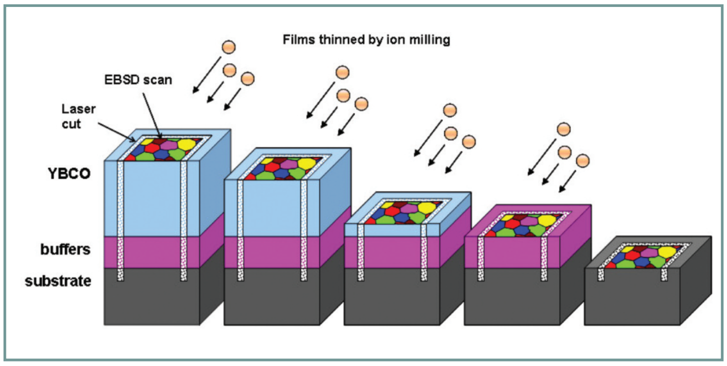

Figure 3. Schematic showing locations of OIM™ measurements.

OIM™ Measurements

OIM™ measurements have been used in a very unique way to characterize the substrate buffer layers and superconducting layer of these tapes. This was done in a Scanning Electron Microscope (SEM) combined with a Broad Ion Beam. OIM™ results were obtained at different layers through the coated conductor to identify the effect of different layers on the final YBCO textures. This is shown schematically in Figure 3.

For good performance these materials must have strong in-plane and out-of-plane alignment of the constituent crystals. The degree to which this has been achieved for the two methods can be observed in Figures 4 and 5. A careful comparison of these two figures reveals that the MOD process provides a more strongly textured final YBCO layer than the PLD process, i.e. the corresponding OIM™ maps are more blue indicating stronger alignment. In addition, the grain structures of the two tapes are quite different.

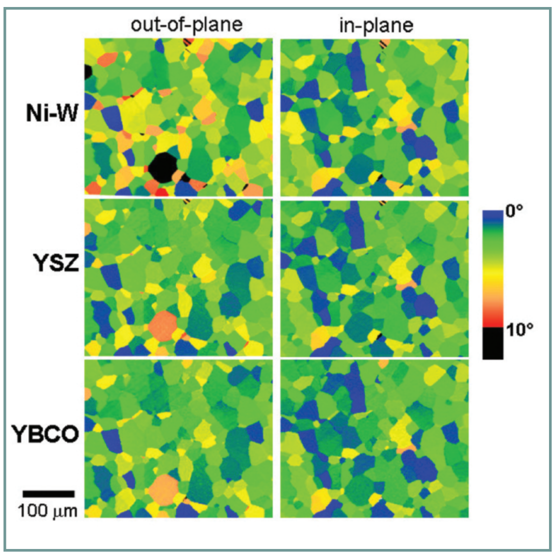

Figure 4. OIM™ maps showing out-of-plane and in-plane alignment for the PLD process.

Conclusions

Controlling the texture is critical to the performance of high temperature superconductor materials, such as YBCO, because of their strong anistropic nature. OIM™ is well suited to characterize the texture in these materials.

Bibliography

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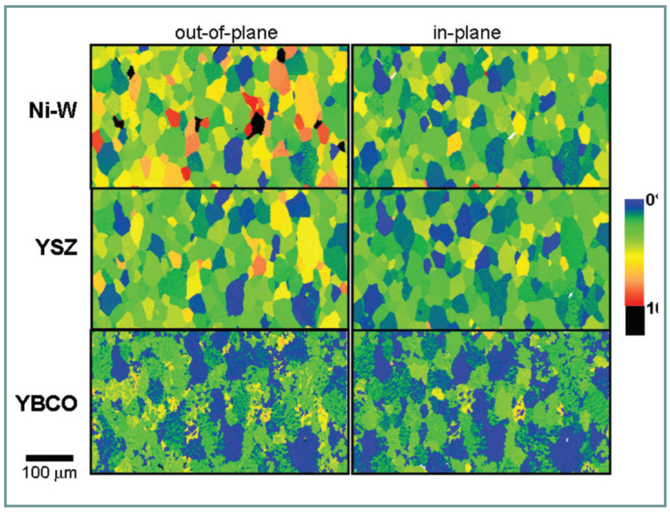

Figure 5. OIM™ maps showing out-of-plane and in-plane alignment for the MOD process.