Applied Thin Films, Inc.

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A T F I

Buffer Technology for Second Generation High Temperature Superconducting (HTS) Wires

Although significant technical progress has been made in superconductivity since the discovery of ceramic-based superconductors (High Tc materials) in 1986, the technology insertion/transfer into the market place has been limited. The primary barrier is associated with the technological/engineering challenge to produce high quality long length wires/tapes that contain these ceramic materials. The market opportunities are enormous to include power utilities, power generation, power transmission, high power & compact motors, power electrical converters, and medical devices. As we move into the digital economy, demands for power of high quality and reliability increase making it essential to implement new technologies such as superconductors. In essence, superconductors represent a revolutionary way in which we will use and distribute electricity in the future. Applications exist both in military and industrial sectors with a total market cap ranging over several billion dollars annually. Only recently, a first generation wire consisting of the ceramic contained within a tube has been developed and is being produced in long lengths. However, the current density in these wires is not sufficiently high (up to 100,000 Amps/cm^2) to offer the competetive advantage over other industrial products.

Based on an innovative processing technology (deformation texturing), a new method developed recently allows the fabrication of YBCO-based superconducting tapes to carry currents over one million A/cm^2. The technology is related to the formation of biaxially textured YBCO films on metal tapes. Extensive R&D efforts related to both materials and processing of the tape technology are underway in US, Europe, and Japan. Based on this promising new development, most of the companies active in the superconductor area are diverting their investments to exploit this technology. Small-sized specimens carrying high current densities (over 1 million amps/cm^2) have been demonstrated by many research groups. However, the scale-up of the concept to produce several kilometer-long conductor tapes is a significant technical and engineering challenge to the industry. Successful scale-up of this technology is related to development of both novel materials and thin-film deposition processes (Applied R&D). There are basically three components to what's now called the coated conductor tape; namely, the substrate metal tape (typically 25-50 µm thick Nickel or Ni-based alloy produced by deformation texturing), followed by deposition of buffer layer/s, and the superconducting YBCO layer (produced by sol-gel, MOCVD, PVD, PLD). The key technological challenge lies in the development of a low-cost, scalable, and high quality buffer layers.

Through SBIR funding from the Ballistic Missile Defense Organization (BMDO), ATFI has been able to establish a strong position in buffer layer technology. Two approaches has been pursued to suit different industrial needs. In one case, ATFI developed a novel metal nitride-based buffer layers. The nitrides provide several desirable features as buffer materials, including a) chemical and thermo-mechanical compatibility with both the metal and YBCO, b) minimal metal diffusion into YBCO, c) good lattice compatibility with YBCO and metal (dimensions and symmetry), d) high electrical and thermal conductivity, and e) high strength and toughness. Also, large-area and low-cost sputtering technology has already been developed for depositing these materials for cutting tool and integrated circuit applications. Our preliminary evaluation of nitride properties suggested few nitrides with suitable properties for HTS applications. Critical current densities of 0.6 MA/cm^2 have been obtained for YBCO grown on TiN buffer layers with ~50 nm thick MgO intermediate layer (Figure 1)

Very recently, through funding from BMDO, ATFI developed a novel and scalable method (patent pending) for direct deposition of high-quality textured yttria stabilized zirconia on the metal substrate. This is a significant development. As shown in Figure 2, the ATFI approach eliminates the need for the first cerium oxide layer commonly used in other schemes. As demonstrated by other researchers, the seed layer deposition is non-trivial and involves careful control of deposition parameters due to concerns related to oxidation of substrate alloy which interferes with the epitaxy of the film being grown. Requirement of this strict process control and other surface treatments poses a significant challenge for scale-up while imposing additional costs to the process.

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The process is termed "ECONO" for Epitaxial Conversion to Oxide via Nitride Oxidation.   A precursor epitaxial nitride layer of composition $Y_{0.2}Zr_{0.8}N$ (YZN) is first deposited on the substrate which is subsequently converted to an epitaxial yttria stabilized zirconia (YSZ) layer by a simple oxidation step.   Current density of 1 MA/cm^2 has been

achieved reproducibly on short samples with YBCO films grown by PLD on ATFI's ECONO™ buffer layer. These promising results have led to the signing of a non-exclusive license agreement with a key industrial partner in the HTS industry to further develop and transfer the ECONO™ process.

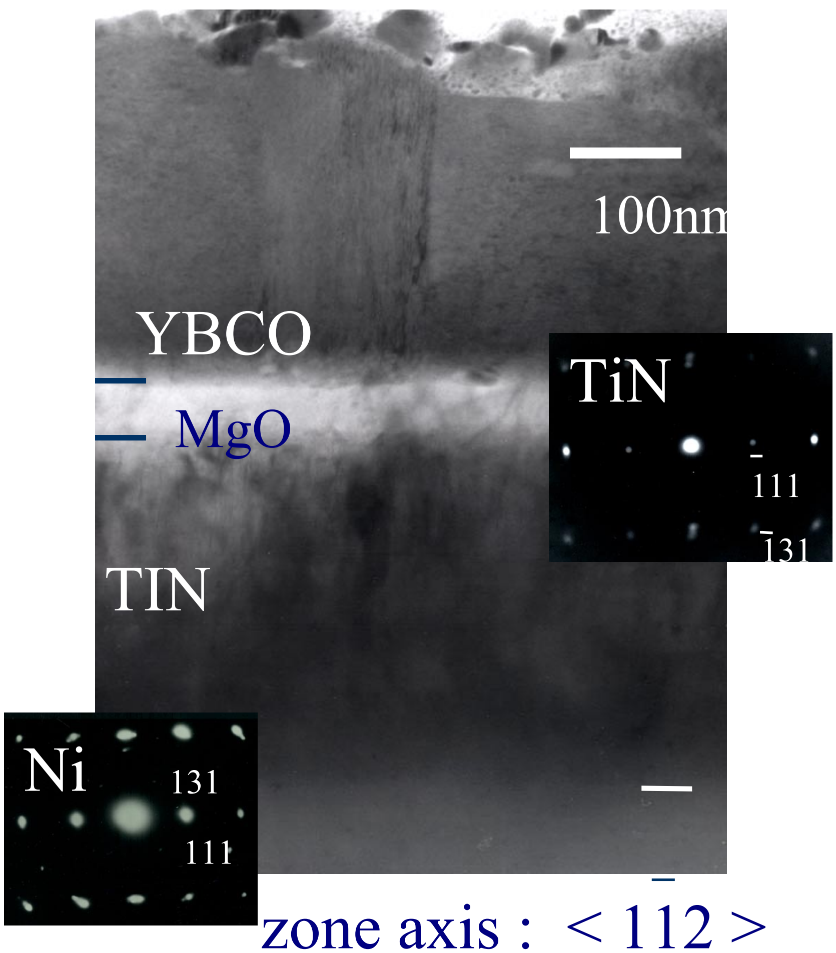

Figure 1. TEM micrograph of Nitride buffer with epitaxial MgO and YBCO layer (Jc = 6 x 10^5 A/cm^2)

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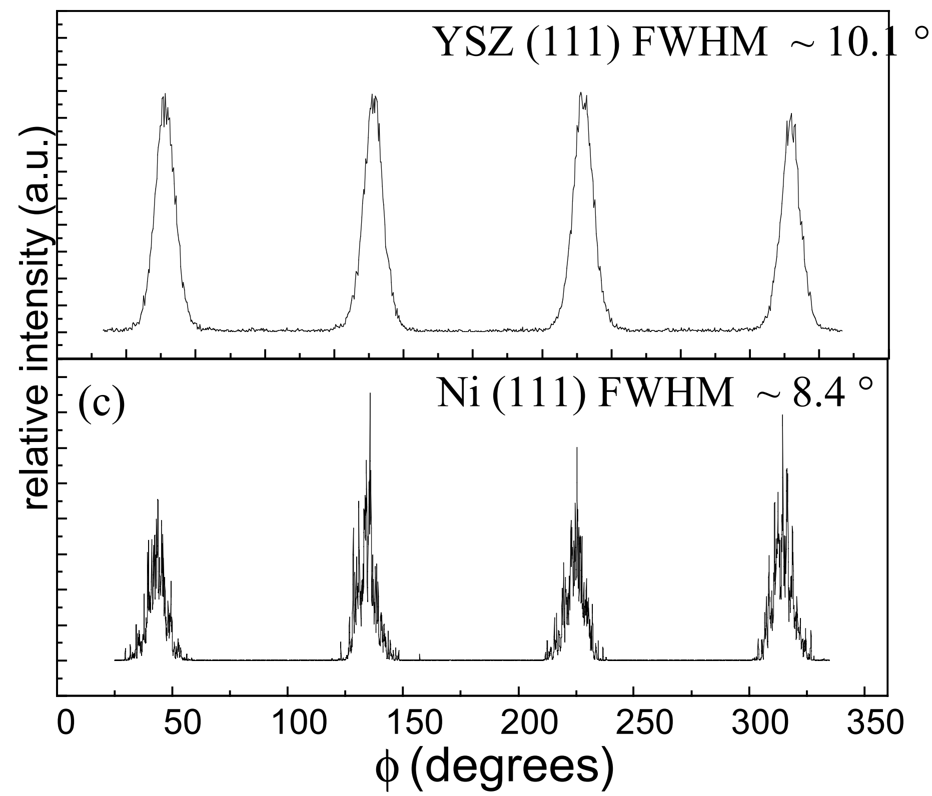

Figure 2. X-ray diffraction Φ scan from ATFI's YSZ layer on RABiTS

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For More Information:

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