IEEE/CSC & ESAS European Superconductivity News Forum (ESNF), No. 7, January 2009
Extended Abstract of Presentation 2E.02 at CCA08, Houston, TX, December 4-6, 2008

Development of Conductive Buffer Architectures Based on IBAD-TiN

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Abstract: Cube textured IBAD-TiN layers with an in-plane orientation below 10° have been deposited reactively using pulsed laser deposition on polished Hastelloy tapes covered with different amorphous seed layers. Metallic buffer layers such as Au, Pt or Ir were grown epitaxially on top of the TiN layer showing texture values similar to the IBAD layer. Smooth layers were obtained using IBAD-TiN with a double layer of Au/Pt or Au/Ir. Biaxially textured YBCO layers were achieved using Nb-doped $SrTiO_3$ as a conductive oxide cap layer showing an in-plane alignment of about 7° and a resistively measured superconducting transition at about 88 K. Finally, an amorphous conducting $Ta_{0.75}Ni_{0.25}$ seed layer was tested successfully for the IBAD-process leading to highly textured TiN films.

I. Introduction

Ion Beam Assisted Deposition (IBAD) offers the possibility to prepare thin textured films on amorphous or non-textured substrates. It was shown within the last decade that cube textured MgO and TiN layers with a thickness of less than 10 nm can be produced on amorphous or nanocrystalline seed layers using this technique [1-3]. In particular, the results corresponding to the in-plane textured growth of TiN are promising for the development of a conducting buffer layer architecture for YBCO coated conductors based on the IBAD approach. One major advantage of TiN is its good electrical conductivity. This would enable the realization of a conductive buffer architecture within the IBAD approach leading to an electrical connection between the superconducting layer and the thick metal substrate in order to avoid thermal destruction of the superconductor in case of an overcurrent situation. Two major challenges need to be solved in order to realize a completely conducting buffer layer stack: (i) an electrically conductive amorphous or nanocrystalline seed layer has to be applied on the metal tape; (ii) additional conducting buffers have to be deposited on the IBAD layer in order to reduce the significant lattice mismatch between TiN (lattice parameter a = 0.424 nm) and YBCO (a ≈ b ≈ 0.386 nm) and to avoid the oxidation of the nitride layer. This paper presents a possible solution for both issues.

II. Experimental

A standard pulsed laser deposition (PLD) geometry was used to prepare biaxially textured TiN films and subsequent buffer layers. An rf plasma source provides the assisting ion beam with a mean ion beam energy of 800 eV under an angle of 45° to the substrate normal using a gas mixture of argon and nitrogen. The texture evolution during film growth was observed *in-situ* using Reflection High Energy Electron Diffraction (RHEED).

Hastelloy® C276 substrates with and without a 100 nm thick amorphous Y_2O_3 seed layer were used for the experiments. In the first step, a biaxially textured TiN thin film was grown using the IBAD process at elevated substrate temperatures. The thickness of the TiN was increased using homoepitaxial growth at a substrate temperature of 700°C in order to preserve the cube texture. Afterwards, Au, Ir and Nb:STO layers were sequently prepared by PLD using a temperature of about 600°C. Finally, a 300 nm thick YBCO layer was deposited on the grown buffer architecture using PLD in a separate high vacuum chamber at a background pressure of 30 Pa Oxygen and a substrate temperature of 810°C. More details can be found elsewhere [4,5].

III. Results and discussion

A. Conducting buffers on IBAD-TiN

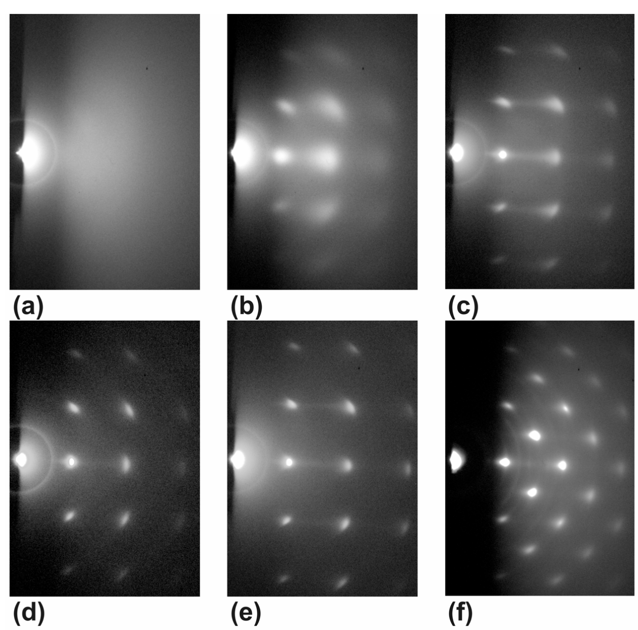
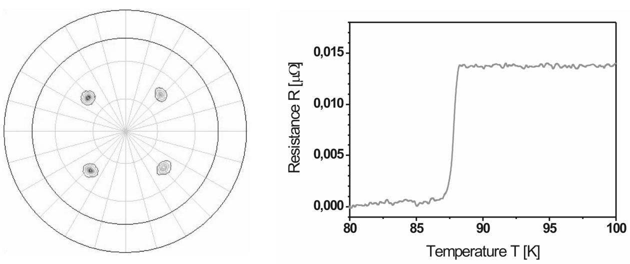


Fig. 1. In-situ RHEED pattern of the complete buffer layer architecture using IBAD-TiN: (a) amorphous surface structure of the Y_2O_3 seed layer at 400°C; (b) biaxially textured TiN of about 5 nm thickness after the IBAD process; (c) 30 nm thick homoepitaxial TiN grown at 700°C; (d) 10 nm thick epitaxial Au layer grown at 600°C; (e) 30 nm thick epitaxial Ir layer grown at 600°C; (f) 120 nm thick epitaxial Nb:STO layer deposited at 550°C.

Highly textured TiN layers were achieved on Hastelloy substrate with an amorphous Y_2O_3 seed layer using PLD with ion-beam assistance at a substrate temperature of 400°C. The texture was preserved to thicker films using homoepitaxial growth of TiN at higher temperatures. A double layer of Au and Ir was used to reduce the lattice misfit between TiN and YBCO. Both layers revealed *in-plane* FWHM values of about 8.5°. Finally, a 120 nm thick Nb:$SrTiO_3$ layer was deposited to ensure the epitaxial growth of the superconducting YBCO layer at higher oxygen pressures and to act as additional diffusion barrier. In-situ RHEED measurements revealed an undisturbed epitaxial growth of the complete buffer layer stack (Fig. 1). The buffered tape was successfully used for the deposition of a 300 nm thick $YBa_2Cu_3O_{7-x}$ layer, showing an in-plane FWHM value of 7.2° and a critical temperature T_c of about 88 K (Fig. 2). More details on the development of this buffer architecture are published elsewhere [4].

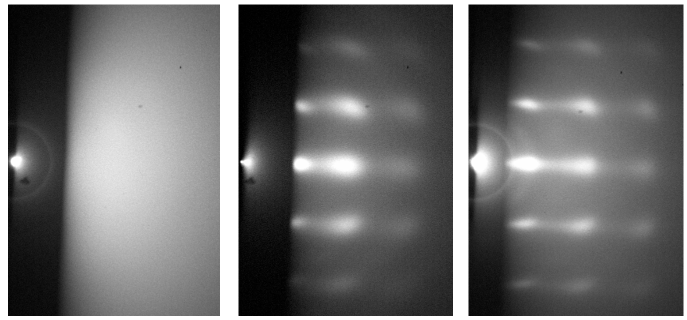


(a) **(b)**

Fig. 2. YBCO grown on Hastelloy/a-Y_2O_3/IBAD-TiN/homo-TiN/Au/Ir/Nb:$SrTiO_3$: (a) YBCO (103) X-ray pole figure; (b) resistive measurement of the superconducting transition for an unpatterned YBCO film

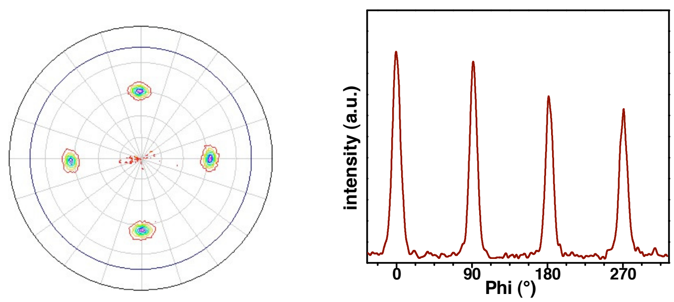
B. Conducting seed layer

Furthermore, amorphous $Ta_{0.75}Ni_{0.25}$ layers (TaNi) with a thickness of 50 nm were directly deposited on electropolished Hastelloy tapes as conducting seed layer using co-sputtering from elemental targets at room temperature. The TaNi layer revealed an amorphous surface structure at elevated temperatures as indicated by the RHEED pattern in Fig. 3a. The results of the RHEED measurements shown in Fig. 3b indicate a similar textured nucleation of IBAD-TiN at elevated temperatures as reported on other seed layers above. Again, the ion-beam assistance was stopped, when the diffraction pattern indicated a strong biaxial alignment. The strong cube nucleation texture was afterwards preserved using homoepitaxial growth as already described in detail previously (Fig. 3c). A 10 nm thick epitaxial gold layer was used to study the surface texture by X-ray diffraction. *In-situ* RHEED investigations indicated an epitaxial growth of this cap layer. Pole figure measurements revealed a strong cube texture with an *out-of-plane* FWHM value of 4° and an *in-plane* value of 9° for a deposition temperature of 350°C during the IBAD step (Fig. 4). In general, the results indicate that amorphous TaNi seed layers are suitable templates for the ion-beam assisted pulsed laser deposition of transition metal nitrides making these layers promising candidates for the realisation of electrically conductive buffer architectures based on the IBAD approach. More details are described in a paper published recently [5].



(a) **(b)** **(c)**

Fig. 3. *In-situ* RHEED pattern showing the surface texture of TiN deposited by IBAD on electropolished Hastelloy substrates: (a) amorphous pattern of the TaNi layer at 350°C; (b) IBAD-TiN film with a thickness of about 5 nm; (c) TiN surface homoepitaxial growth at 700°C having a film thickness of 30 nm.



(a) **(b)**

Fig. 4. Au layer with a thickness of 10 nm deposited at 600°C on a Hastelloy/TaNi/IBAD-TiN template: (a) X-Ray (111) pole figure showing a strong cube texture; (b) corresponding phi-scan of the Au (111) pole figure;

ACKNOWLEDMENT

The work and results reported in this letter were partially obtained with research funding from the European Community under the Sixth Framework Programme Contract No. 516858: HIPERCHEM.

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