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Superconducting Tl-Ba-Ca-Cu-O films deposited on Ag substrates

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Thin Tl-Ba-Ca-Cu-O (TBCCO) films were prepared on texturized silver tape in a two-step procedure. First, Ba-Ca-Cu-O precursors were deposited from an aerosol generated ultrasonically from metalorganic solution of Ba, Ca and Cu acetylacetonates (2,4-pentanedionates) with the thickness of the order of a couple of microns. The tape texturing has been obtained by a metallurgical processing combined with the heat treatment. Pole figure measurements revealed a relatively good biaxial texturing of the substrate used. Then, second, precursors were thallinated in a 1-zone reaction chamber using a crude Tl-Ba-Ca-Cu-O pellet containing appropriate amount of Tl_2O_3 as a source of Tl_2O. A closed-crucible method has been used for thallination. The best critical temperature T_c values of synthesized films were from the interval of 100 K to 108 K. X-ray diffraction patterns revealed a very strong grain orientation. The morphology investigation showed rectangular plate-like grains on the sample surface. X-ray diffraction and pole figure measurements revealed that these grains, besides a strong *c*-axis orientation, are subjected also to a relatively good *a*-axis orientation. It means, at least in a first approximation, that the film texturing follows the texturing of the substrate used. The optimization of biaxial texturing of both, silver substrate as well as TBCCO films grown on such substrates is currently on the way.

1. Introduction

There is a continuous interest in developing Tl-based thick films for high-current and high-field applications[1]. For this purpose, considerable lengths of tape wire must be prepared which requires both, a suitable and flexible carrier substrate and the use of industrially scalable deposition method able to obtain relatively thick superconducting films. It is already recognized that the opened approach of depositing films on carrier substrate is superior to that of OPIT (oxide powder-in-tube) method because of better intergrain connectivity as well as better grain orientation. As a substrate with suitable structural properties and a good chemical compatibility with the grown Tl-based films, the silver cubic-textured substrate is used[2-7]. A good crystal alignment of superconducting grains on metal substrate in both *c*-axis and *a*-axis orientations is required from the point of view of reduced weak-link behavior. By combination of the rolling and the heat treatment it is possible to obtain a relatively high degree of texture in Ag-tapes. A cubic-textured silver tape is used as a substrate also in a case of Y-based (YBCO) superconducting films[8]. Recently, for both types of HT_c films i.e. Tl-based as well as Y-based, the Ni-based rolling assisted biaxially textured substrates (RABiTS)[9,10] with CeO_2 and /or YSZ buffer layers are also used.

2. Experimental

As a substrate we used a commercial GOODFELLOW Ag-foil initially cold rolled with either 99.9% or 99.99% purity. The X-ray diffraction pattern of an initial state of the tape with 99.9% purity is shown in Fig. 1.

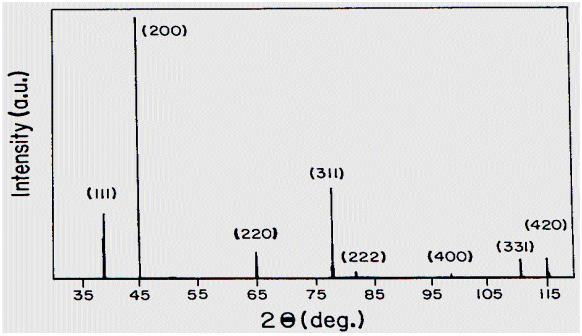

Fig. 1. X-ray diffraction pattern of GOODFELLOW 99.9% purity Ag-foil used for Ba-Ca-Cu-O precursor deposition.

A pronounced texture and orientation perpendicular to the substrate surface may be seen from the diagram. We have found, however, that the texture depends rather strongly on the tape thickness reduction during the rolling process. Prior to the precursor deposition the foil underwent combined mechanical and thermal treatment at 400°C/1h and 800°C/2h. The foil texture has been controlled by X-ray diffraction and pole figure measurements. Superconducting Tl-based films were prepared on this type of substrates in two steps.

The Ba-Ca-Cu-O precursors were deposited on texturized silver substrates from an aerosol containing organometalic Ba, Ca and Cu acetylacetonates (2,4-pentanedionatos) dissolved in dimethylformamide. Such a solution was nebulized ultrasonically, as an aerosol carrier gas we used purified air. The precursor samples were then reacted with thallium vapour in a closed alumina crucible using a crude Tl-Ba-Ca-Cu-O pellet as asource of Tl_2O. Superconducting samples were pole figure measurements and by EDAX analysis.

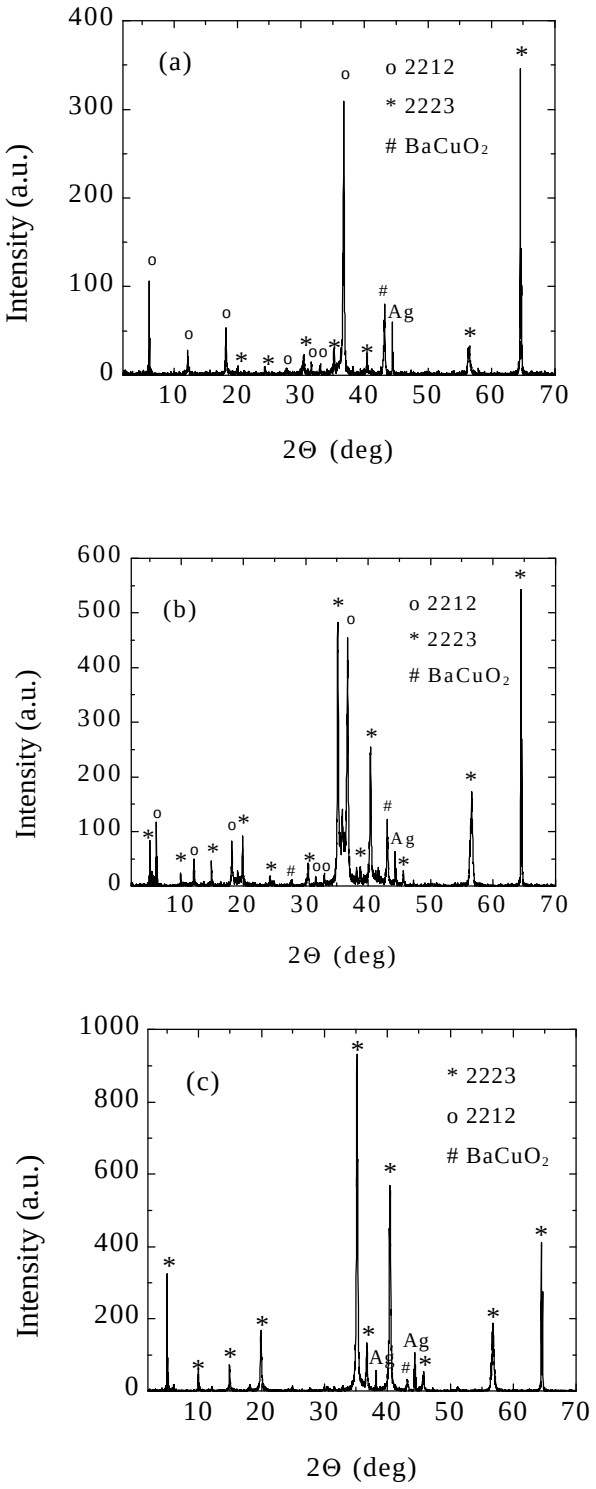

Fig. 2. X-ray diffraction pattern of precursors thallinated at 870°C/30 min. with various initial amount of Tl_2O_3; (a) sample AC-197 with nearly pure 2212 phase, (b) AC-198 with a mixture of 2212 and 2223, (c) AC-208, nearly pure 2223 phase.

A characterized by X-ray diffraction, R(T) measurements, SEM morphology investigation of samples was also performed.

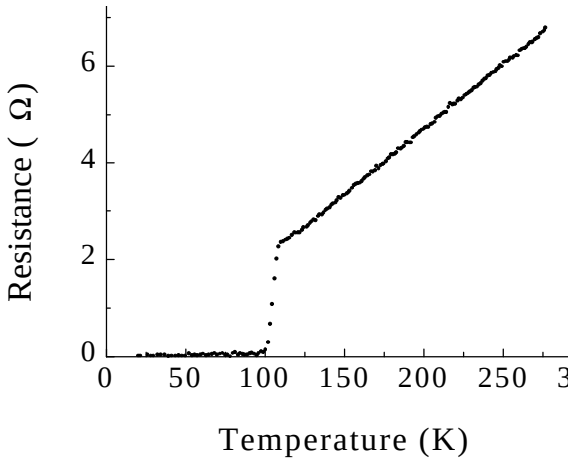

Fig. 3. Typical R(T) dependence of prepared superconducting samples.

3. Results and discussion

A typical X-ray diffraction pattern from thallinated films showing only *c*-axis peaks is shown in Fig. 2. The difference among these 3 films is in an initial amount of Tl_2O_3 in a crude pellet used for thallination. In Fig. 2(a), the pattern of a nearly pure Tl-2212 phase is presented. In Fig. (2b), there is a mixture of Tl-2212 and Tl-2223 phases. The Fig. 2(c) shows X-ray pattern of nearly pure Tl-2223 phase. In some cases, traces of Tl-1223 phase or stable $BaCuO_2$ may be seen.

A typical R(T) dependence of prepared superconducting films is plotted in Fig. 3. The critical temperature T_c values of all synthesized films were from the interval of 100 K to 108 K.

The morphology investigation revealed plate-like, in some cases rectangular grains on the film surface, parallel with the surface of the tape (Fig. 4). This observation is in correlation with the X-ray diffraction pattern of the film showing strongly *c*-axis oriented crystallites. It also means that a number of *a*-axis oriented grains exist if compared to the *a*-axis orientation of the substrate cubic structure. This mutual grain orientation is currently optimized using 2-zone thallination furnace allowing better control of the sample sintering temperature on one hand and, the value of the induced partial pressure of pTl_2O and that of needed partial pressure of oxygen pO_2 on the other.

The pole figure measurements (not presented here) show also relatively well oriented superconducting film on {001}<110> textured silver tape.

4. Conclusions

Following the irreversibility lines of various HT_c superconductors and their phases[1], YBCO and Tl-1223 materials are most important for power applications at 77K. In our case we prefer development of Tl-based films which may be synthesized by industrially scalable spray pyrolysis method.

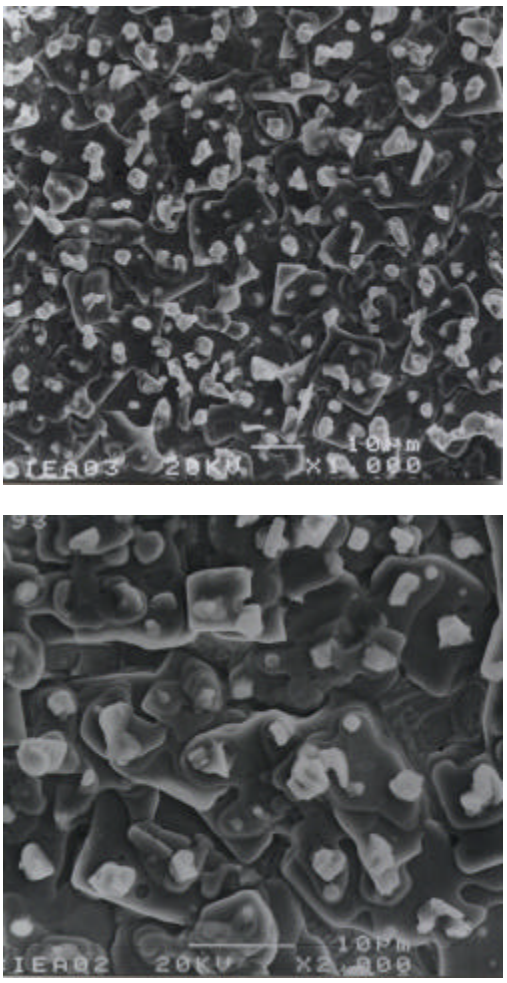

FIG. 4. Typical surface morphology of superconducting films. Sample AC-193 with 1000x (top) and 2000x (bottom) magnification.

To obtain sufficiently high J_c values it is advisable to use bi-axially textured substrates, in our case it is flexible silver tape. We succeeded so far to prepare nearly pure 2212 and/or 2223 Tl-phases with a strong *c*-axis orientation of the superconducting plate-like grains rectangularly shaped in some cases. A work is currently on the way to optimize thallination conditions by using a 2-zone furnace with the aim to grow Tl-1223 phase only. A presence of fluorine in the films may also help to stabilize a growth of this phase. This might be performed by a partial substitution of oxygen by fluorine due to a difference in ionic radii of these two gases[11,12].

Acknowledgements

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