Available online at www.sciencedirect.com

ScienceDirect

Ceramics International 41 (2015) 3624–3630

CERAMICS INTERNATIONAL

www.elsevier.com/locate/ceramint

Influence of laser power on orientation, microstructure and electrical performance of $YBa_2Cu_3O_{7-x}$ film prepared on (001) $SrTiO_3$ single crystal substrate by spray atomizing and coprecipitating laser chemical vapor deposition

Pei Zhao[a,*], Ying Wang[a], Zhi liang Huang[a], Yang wu Mao[a], Goto Takashi[b]

[a]School of Material Science and Engineering, Wuhan Institute of Technology, Wuhan 430074, China
[b]Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Sendai 980-8577, Japan

Received 9 September 2014; received in revised form 4 November 2014; accepted 4 November 2014
Available online 12 November 2014

Abstract

$YBa_2Cu_3O_{7-x}$ film was prepared on (001) $SrTiO_3$ single crystal substrate by spray atomizing and coprecipitating laser chemical vapor deposition. At laser power of 101–116 W (corresponding deposition temperature was 893–942 K), *a*-axis-oriented $YBa_2Cu_3O_{7-x}$ film was prepared, which showed an epitaxial growth mode of $YBa_2Cu_3O_{7-x}$ [100]||$SrTiO_3$ [001] ($YBa_2Cu_3O_{7-x}$ [001]||$SrTiO_3$ [100]). The *a*-axis-oriented $YBa_2Cu_3O_{7-x}$ film had critical temperature of 75–82 K, with critical current density from 0 to 0.4 MA cm^{-2}. At laser power of 167–181 W (corresponding deposition temperature was 1093–1154 K), *c*-axis-oriented $YBa_2Cu_3O_{7-x}$ film was obtained, whose epitaxial growth mode was $YBa_2Cu_3O_{7-x}$ [001]||$SrTiO_3$ [001] ($YBa_2Cu_3O_{7-x}$ [100]||$SrTiO_3$ [100]). A *c*-axis-oriented $YBa_2Cu_3O_{7-x}$ film prepared at a deposition rate of 14 μm h^{-1} showed a high critical temperature of 91 K and critical current density of 2.8 MA cm^{-2}.

Keywords: $YBa_2Cu_3O_{7-x}$ film; Laser chemical vapor deposition; $SrTiO_3$ single crystal

1. Introduction

For preparation of the second generation high-temperature superconducting $YBa_2Cu_3O_{7-x}$ (YBCO) film, various techniques such as metalorganic deposition using trifluoroacetates [1], pulsed laser deposition [2], sputtering [3], molecular beam deposition [4], and metalorganic chemical vapor deposition (MOCVD) [5–8] have been attempted. Among these techniques, the MOCVD has been considered as a promising approach due to advantages of environment-friendly preparation process, uniform coverage, high controllability for film composition, large area coating for substrate with complex shape and relatively high deposition rate [5–8]. More importantly, in industrial application, the MOCVD is a kind of low-cost vacuum technique that is suitable for scaling up in continuous preparation by a belt driven reel-to-reel system [9].

In order to make MOCVD a superior technique for preparation of YBCO film, several novel MOCVD-based techniques, for instance, plasma [10,11], magnetic-field [12,13] and laser [14,15] enhanced MOCVD, have been developed, among which the laser enhanced MOCVD (abbreviated as laser CVD) is the most potential method in preparing YBCO film in the view point of industrial application. Because the laser CVD can prepare highly performed YBCO film at a significant high deposition rate (R_{dep}). The reason lies in greatly reduced reaction activation energy for precursor molecules by irradiation of laser beam [14,15]. In preparation of YBCO film, our group has taken the lead by using laser CVD and obtained high quality YBCO film at high R_{dep} ranged from 57 to 101 μm h^{-1}. The YBCO film was prepared by a laser CVD equipped with three heating tanks for solid precursors of $Y(DPM)_3$, $Ba(DPM)_2$ and $Cu(DPM)_2$ [14,15]. Composition of

*Corresponding author.
E-mail address: zhaopei410@163.com (P. Zhao).

http://dx.doi.org/10.1016/j.ceramint.2014.11.027
0272-8842/

the YBCO film was controlled by adjusting heating temperature of the three precursor tanks. This laser CVD is applicable for laboratory research; however, it is unsuitable for industrial application. Because precise composition control of YBCO film by adjusting heating temperature of the three precursor tanks is extremely difficult. Another reason is that the heating tanks cannot supply continuous precursor gas for long deposition time due to small volume inside the tanks for solid precursor. Aiming to these problems, we have improved the laser CVD by developing a spray atomizing and coprecipitating liquid precursor supply system (termed SAC laser CVD) (Fig. 1). In the present study, we prepared YBCO film on (100) $SrTiO_3$ single crystal by the SAC laser CVD, and investigated influence of laser power on preferred orientation, epitaxial growth mode, crystallinity, in-plane orientation, microstructure and electrical performance of the YBCO film.

2. Experimental

(100)-Oriented $SrTiO_3$ single crystal (STO) was used as a substrate. Schematic of SAC laser CVD apparatus was shown in Fig. 1. A continuous wave Nd:YAG laser (1064 nm) with laser power (P_L) output up to 200 W was employed. $Y(DPM)_3$, $Ba(DPM)_2$ and $Cu(DPM)_2$ (DPM, dipivaloylmethanate) were mixed in a molar ratio of Y:Ba:Cu = 1:2.0:3.0 and then dissolved into Tetrahydrofuran (THF; C_4H_8O) with a Y $(DPM)_3$ concentration of 0.01 mol L^{-c}. Supply rate of the solution was 1.0×10^{-5} L/s^{-1}. Flow rates of Ar and O_2 gases were 1.52 Pa m^3 s^{-1} and 0.85 Pa m^3 s^{-1}, respectively. Preheating temperature for substrate was 923 K. Deposition temperature (T_{dep}) was measured with a thermocouple at the back side of the substrate. Total pressure of reaction chamber was 800 Pa and deposition time was 60 s.

Phase of YBCO film was measured by X-ray diffraction (XRD; Rigaku RAD-2C). Crystallinity of YBCO film was evaluated by the full-width at half-maximum (FWHM) of the ω-scan (rocking curve) on the (005) reflection. In-plane orientation of YBCO film was evaluated by the FWHM of the ϕ-scan on the (103) reflection, which was measured by pole-figure X-ray diffractometer (XRD; Rigaku Ultima IV). Microstructure was observed by field-emission scanning electron microscope (FESEM; JEOL JSM-7500F). Schematic of epitaxial growth mode of YBCO film was drawn by the VESTA software package [16]. Composition of YBCO film was measured by inductively coupled plasma (ICP-AES; Simadzu ICPS-7510). Electrical conductivity was measured at temperature from 30 to 300 K by dc four-probe method.

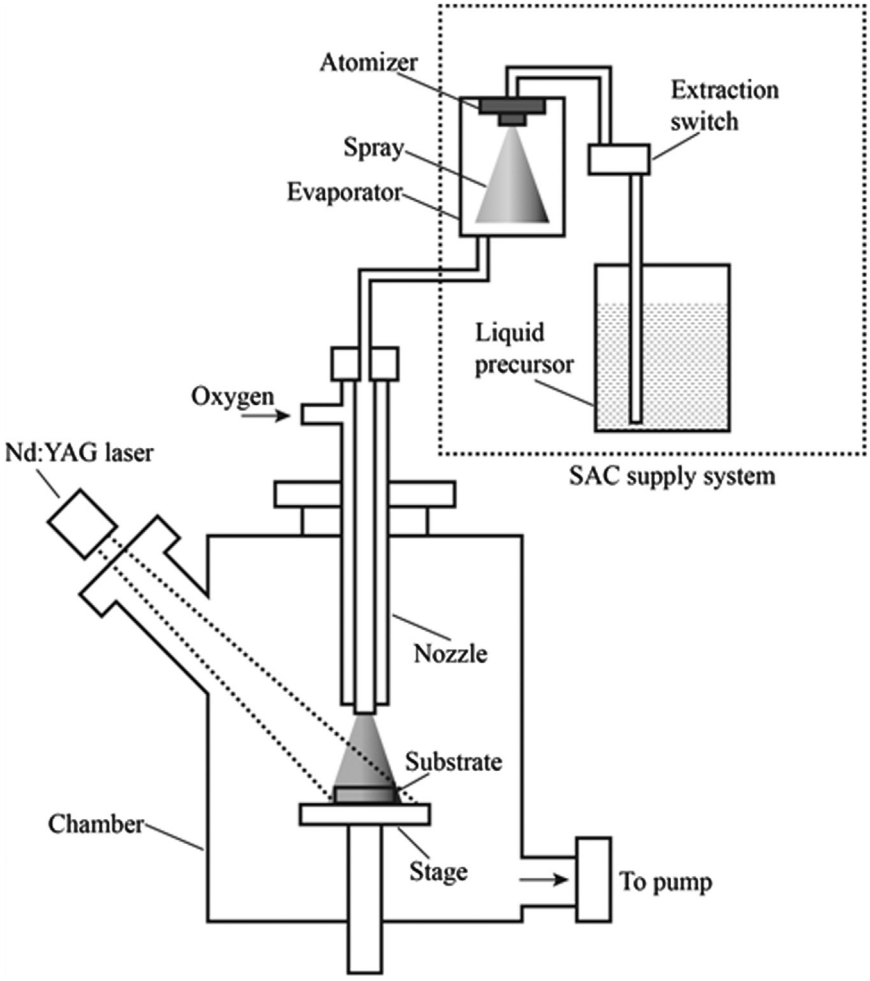

Fig. 1. Schematic of SAC laser CVD apparatus.