Wed-Af-Po3.18-06 [42]

Improvement of Jc Properties for Hf and La co-doped Gd123 Films Fabricated by Fluorine-Free MOD Method

J. Fukui[1], T. Hatano[1], O. Miura[1] and R. Kita[2]

1. Tokyo Metropolitan University,1-1Minamiosawa,Hachioji, 192-0397, Japan

2. Shizuoka University, 3-5-1 Johoku, Naka-ku, Hamamatsu City, 432-8011, Japan

INTRODUCTION

$GdBa_2Cu_3O_y$ (Gd123) superconductors

- Having a high critical temperature (Tc=96K) .
- Having a high critical current density Jc in high magnetic fields .

→ Gd123 superconductors have been actively researched for second-generation coated superconductors.

FF-MOD (Fluorine-Free Metal-Organic Deposition) method

FF-MOD is expected to be more suitable for mass production of Gd123 coated conductors than others, because it is a simple and cost-effective process.

In this study,

we have fabricated Hf and La co-doped FF-MOD $GdBa_2Cu_3O_y$ (Gd123) thin films on $LaAlO_3$ substrates and investigated their flux pinning properties.

FABRICATION PROCESS (FF-MOD process)

The solutions for coating were prepared by mixing stoichiometric amounts (Gd :Ba:Cu=1:2:3) of Gd, Ba, and Cu 2-ethylhexanate with La 2-ethylhexanate and tetrabenzylhafunium up to 10 mol% of Hf.

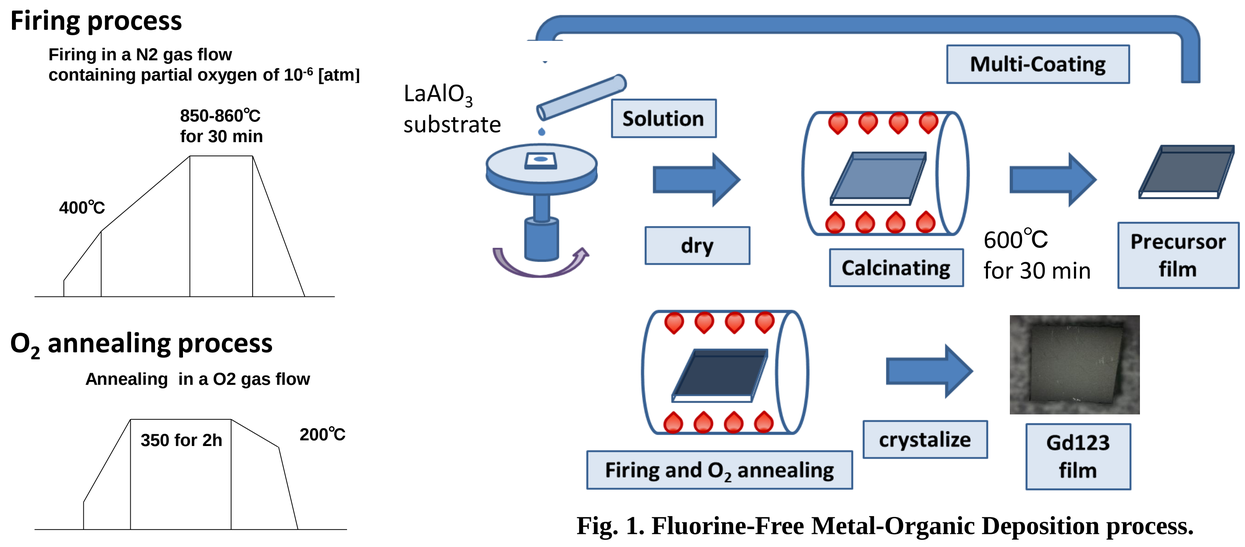
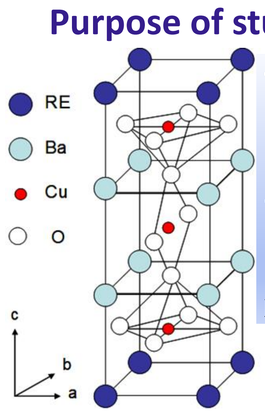


Fig. 1. Fluorine-Free Metal-Organic Deposition process.

Result

Purpose of study



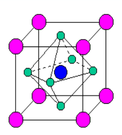
RE123 crystal structure model

- Hf doping

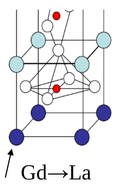
To make $BaHfO_3$ pinning center

- La doping

To decrease hole density and promotion of crystallization



$BaHfO_3$ (Perovskite structure)



Gd→La (replaced slightly)

Improvement of J_c-B properties by introducing pinning center and promotion of crystallization.

SEM images

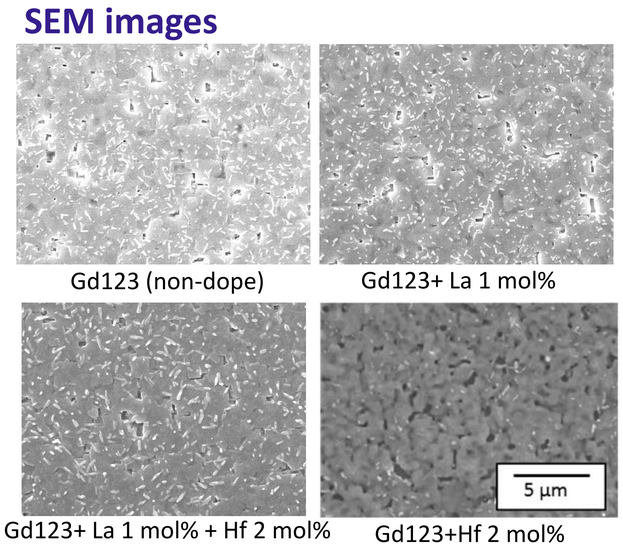


Fig. 2. SEM images for the surface of all films.

Decreasing the number of the hole by La doping.

XRD Patterns

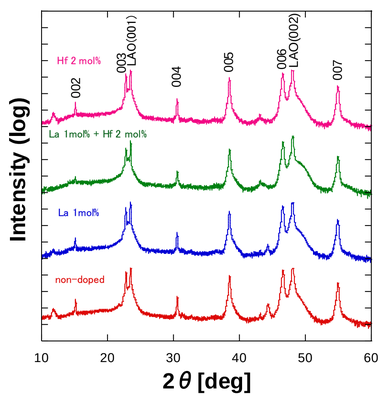


Fig. 3. XRD patterns of all films.

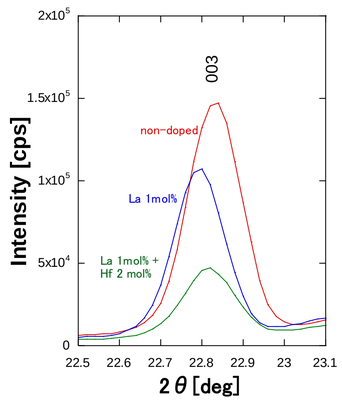


Fig. 4. (003) peak of XRD patterns.

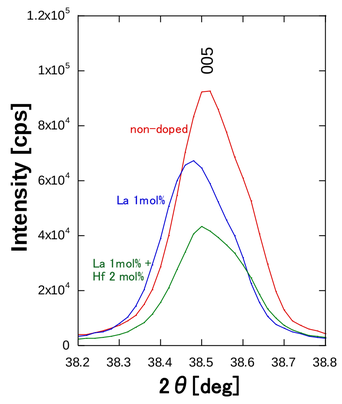


Fig. 5. (005) peak of XRD patterns.

- All films were crystallized into the c-axis oriented direction be-cause the XRD peaks against (0 0 n) were clearly observed.
- It can be confirmed that La 1 mol% film has the narrowest half width of (0 0 n) peaks in all films. This is thought to come from improvement of crystallinity of RE123 by adding La.

Critical temperature

Tab. 1. Critical temperature for all films.

Sample	T_C [K]
Non-doped	89.8
La 1 mol%	90.7
Hf 2 mol%	90.1
La 1 mol% + Hf 2 mol%	89.9

Tc for all films indicated around 90 K, and Tc varied little by Hf and La doping.

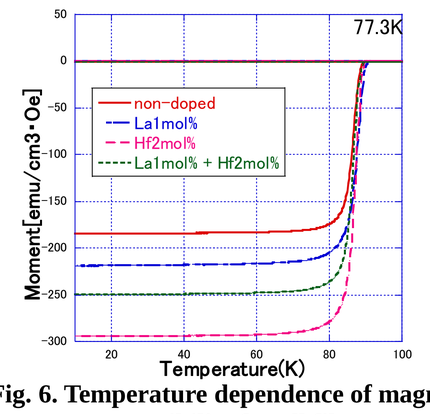


Fig. 6. Temperature dependence of magnetic susceptibility for all films.

CONCLUSIONS

- We have successfully fabricated Hf and La doped FF-MOD Gd123 thin films on $LaAlO_3$ single crystal substrates by using tetrakislhafnium as an organic metal salt.
- J_c improved by Hf doping, and the maximum J_c of 2.72 MA cm^{-2} at 77.3 K, 0 T, and 0.27 MA cm^{-2} at 1 T were achieved for Hf 10 mol% doped film, which are three times larger than ones for non-doped film.
- J_c further improved by Hf and La doping, J_c of 0.253 MA cm^{-2} at 1 T were achieved for Hf 2 mol% and La 1mol% doped film.

The effective APCs are introduced by Hf doping to improve F_p in high magnetic fields.

Promoting crystallization of Gd123 by La doping bring about increase of J_c in low fields.

Magnetic field dependence of the critical current densities

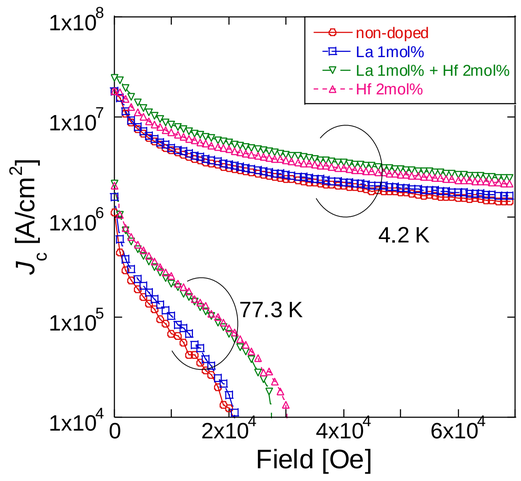


Fig. 7. Magnetic field dependence of the critical current densities for all films.

Tab. 2. Critical current densities for all films.

thin film	J_C [MA/cm²] (77.3 K)		J_C [MA/cm²] (4.2 K)	
	0T	1T	0T	1T
non-doped	3.03	0.145	18.1	4.65
La 1 mol%	2.99	0.159	17.9	4.94
Hf 2 mol%	2.06	0.256	18.2	6.98
La 1 mol% + Hf 2mol%	3.10	0.253	24.3	8.39

- The maximum Jc of 3.10 MA cm-2 at 0 T was obtained for La 1 mol% + Hf 2 mol% co-doped film, and 0.256 MA cm-2 at 0.5 T was obtained for Hf 2 mol% doped film were at 77.3 K, which were 1.6 times larger than those for non-doped film.
- La 1 mol% + Hf 2 mol% co-doped film achieved the highest Jc at all magnetic fields at 4.2 K.

Magnetic field dependence of flux pinning force

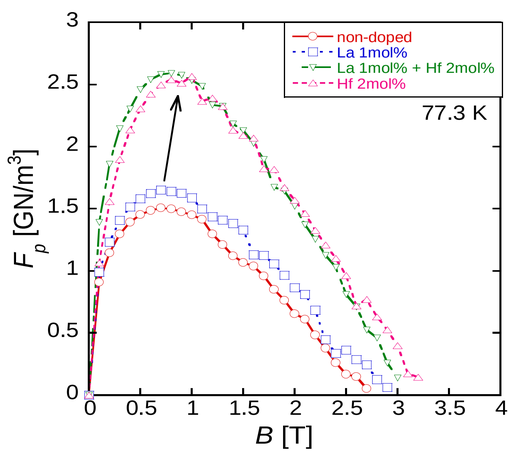


Fig. 8. Magnetic field dependence of flux pinning force for all films at 77.3 K.

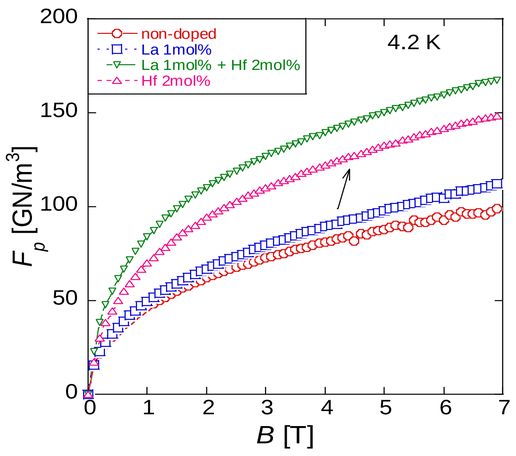


Fig. 9. Magnetic field dependence of flux pinning force for all films at 4.2 K.

- The maximum Fp of 2.59 GN/m3 at 0.8 T obtained for La 1 mol% + Hf 2 mol% doped film, which were 1.7 times larger than those for non-doped film. Furthermore, the peak of Hf doped films Fp gradually shifted to the high field side.
- This reveals that the effective artificial pinning centers (APCs) are introduced by Hf doping resulting in enhancement of Fp in high magnetic fields. Fig. 9. shows Fp for all films at 4.2 K. Doping La 1 mol% + Hf 2 mol% improve the Fp in all magnetic fields. Fp monoton-ically increased with increasing Hf doped amount.

Hf doped amount dependence of effective pinning density and elementally pinning force

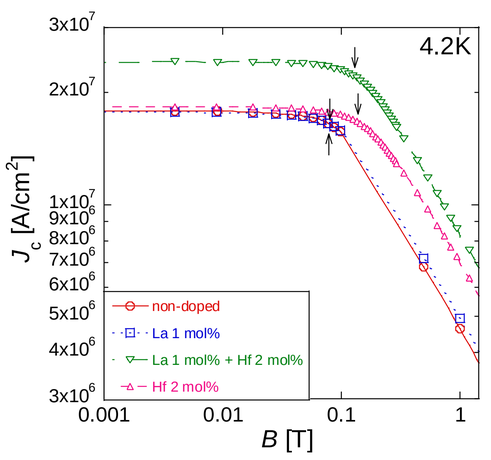


Fig. 10. Double logarithmic plots of Jc-B properties at 4.2 K for all films. Arrow indicicates the characteristic B* for each film.

Single voltex pinning model

$$B^* = \Phi_0 n_{eff} \quad J_c B^* = n_{eff} f_p$$

Φ_0: the flux quantum

n_{eff}: effective pinning density

Tab. 3. Characteristic field B^*, Flux pinning force $F_p(B^*)$, the effective pinning center density n_{eff}, and the elementary pinning force f_p for all films

Thin films	B^* [T]	$F_p \times 10^{10}$ [N/m³]	$n_{eff} \times 10^{13}$ [m^{-2}]	$f_p \times 10^{-4}$ [N/m]
non-doped	0.086	1.40	4.16	3.37
La 1mol%	0.089	1.44	4.30	3.34
La 1mol% + Hf 2mol%	0.144	3.11	6.96	4.47
Hf 2mol%	0.152	2.48	7.35	3.37

- The number of n_{eff} increased by Hf doping. Especially La 1 mol% + Hf 2 mol% film obtained the maximum value of 73.5 μm^{-2} at 4.2 K. This is more than 1.77 times as large as that for non-doped film. On the other hand, n_{eff} was almost unchanged by La doping. Moreover f_p was little changed by La and Hf doping.
- From these results it was confirmed that only Hf doping brought about the increase of n_{eff} which may be $BaHfO_3$ artificial pins reported by other process in Hf doped Gd123 firms