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The study of pinning center formation in $Sm_1Ba_2Cu_3O_{7-d}$ coated conductor by reactove co-evaporation method

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ABSTRACT

We investigated the pinning centers formation in $Sm_{1+x}Ba_2Cu_{3+y}O_{7-d}$(SmBCO) coated conductor by reactive co evaporation method. The SmBCO film was deposited on the IBAD-MgO template with the structure of SmBCO/LMO/MgO/Y_2O_3/Al_2O_3/Hastelloy using EDDC (Evaporation Using Drum in Dual Chambers) process. We investigated the phase formations as pinning centers with the change of composition ratio of Sm:Ba:Cu. We found out that several phases were observed in the SmBCO matrix such as Sm_2O_3 and Sm/Ba anti-site, which was confirmed by TEM analysis, and good superconducting properties under high magnetic field could be achieved by virtue of those pinning centers. We also investigated the effect of deposition process parameters such as deposition rate on the pinning centers formations. Three 12 cm long samples with a deposition rate of 11 nm/min, 21 nm/min and 27 nm/min were obtained, and superconducting properties were measured using a physical property measurement system (PPMS) and the microstructure was analyzed using a transmission electron microscope (TEM) analyzer . The magnetic field dependence of the critical current was measured using the PPMS in the direction of the magnetic field parallel to the c axis of the superconducting thin film. The highest normalized critical current was obtained at a deposition rate of 21 nm/min, followed by 27 nm/min and 11 nm/min.

The structure of the batch type EDDC deposition system

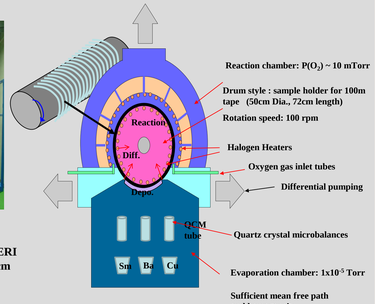


Fig. 1. The photograph of EDDC installed in KERI (Drum style : sample holder for 100m tape , 50cm diameter: 50cm, length: 72cm)

The effect of compositional ratio of Sm_{1+X} Ba_2 Cu_{3+Y} O_{7-d} on the superconducting properties

❖Sample preparation

Sample ID	Composition ratio (At%) (Sm:Ba:Cu)	T_c (K)	J_c (MA/cm²)	Ic(1T)/Ic(0T) 77K	65K	60K
1	**17:31:51**	90.6	3.6	0.14		0.27
2	**19:32:49**	91.2	3.2	0.24	0.32	
3	**20:30:50**	91.3	5	0.29	0.40	

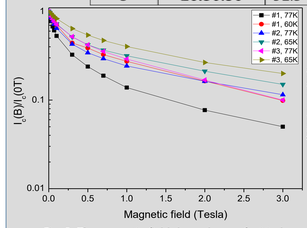


Fig. 2. The magnetic field dependence of critical currents

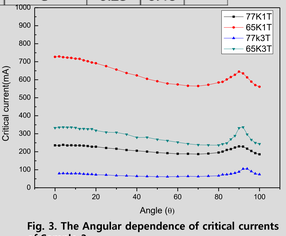


Fig. 3. The Angular dependence of critical currents of Sample 3

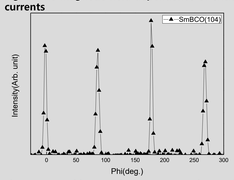


Fig. 4. XRD Phi scan of SmBCO(104) plane of Sample 3

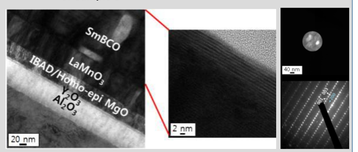


Fig. 5. TEM image of SmBCO film of Sample 3

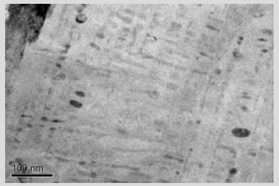


Fig. 6. Side view by TEM of SmBCO film of Sample 3

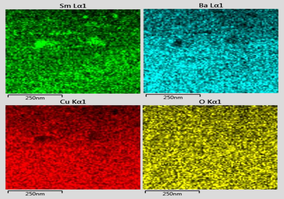
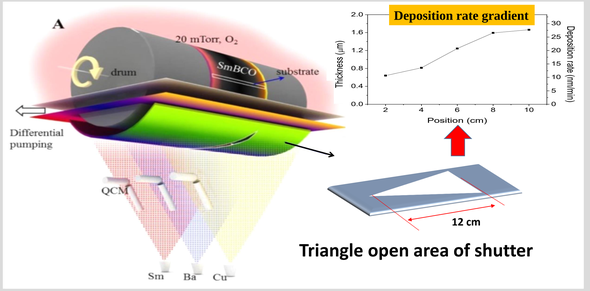


Fig. 7. EDS mapping of SmBCO film of Sample 3

1)The magnetic field dependence of critical current was highly dependent on the composition ratio of SmBCO film. In case of composition ratio of Sm:Ba:Cu = 20:30:50, the value of $I_c(1T)/I_c(0T)$ was as large as 0.29 at 77 K.
2)The broad peak at Θ = 0 (B//c-axis) in the angular dependency of critical current was observed, which means that c-axis co-related pinning center was formed in SmBCO film.
3)Pinning centers with the shape of particle and rod were observed in the TEM images

The effect of deposition rate of Sm_{1+X} Ba_2 Cu_{3+Y} O_{7-d} on the superconducting properties



<Deposition conditions>

1. **Substrate temp.: 790°C**
2. **Oxygen partial pressure in reaction chamber: 20 mTorr**
3. **Rotation speed of drum: 100 RPM**
4. **Deposition Time: 1hour**
5. **Substrate: width(4mm), length(12cm)**
6. **Structure: SmBCO/LMO/MgO/Y_2O_3/Al_2O_3/SUS**
7. **Corresponding deposition rate->**
   Sample #1: 27 nm, Sample #2: 21nm
   Sample #3: 11 nm

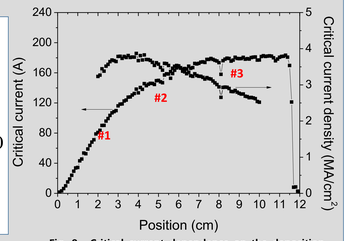


Fig. 8. Critical current dependence on the deposition rate of SmBCO film

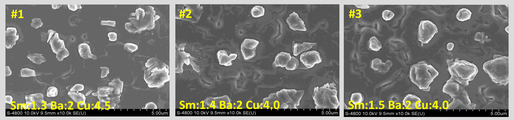
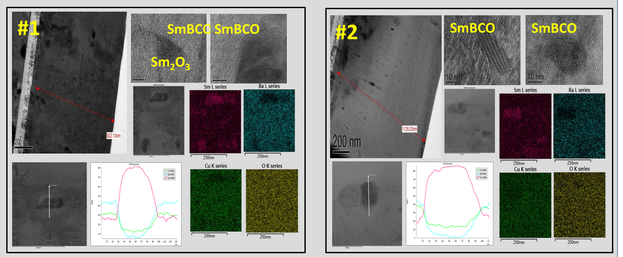


Fig. 9. Surface morphology and composition ratio of Sm_{1+x} Ba_2 Cu_{3+y} $O_{7-\delta}$ thin film



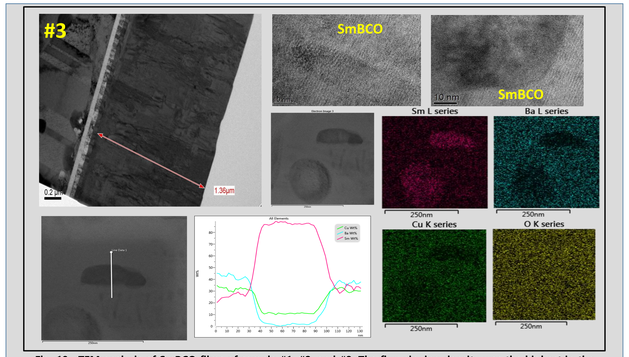


Fig. 10. TEM analysis of SmBCO films of sample #1, #2, and #3. The flux pinning density was the highest in the sample #2 with a deposition rate of 21 nm/min

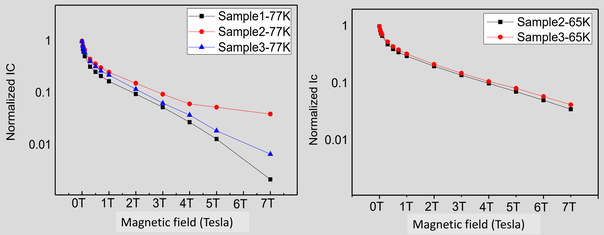


Fig. 11. The magnetic field dependence of critical currents of sample #1, #2, and #3. The highest normalized critical current under magnetic field was obtained at a deposition rate of 21 nm/min, followed by 27 nm/min and 11 nm/min.

Conclusion

- The magnetic field dependence of critical current was highly dependent on the composition ratio of SmBCO film.
- The magnetic field dependence of critical current was highly dependent on the deposition rate of SmBCO film.
- The broad peak at Θ = 0 (B//c-axis) in the angular dependency of critical current was observed, which means that c-axis co-related pinning center was formed in SmBCO film.
- Pinning centers such as Sm_2O_3, Sm/Ba antisite with the shape of particle and nano-rod were observed in the TEM images
- As a result of confirming the cross section of the TEM, it was confirmed that the phases related to the Sm element were present in the SmBCO thin film, and it was mixed with one dimensional point or two dimensional rod form.