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Short-time fabrication and trapped field distributions of large REBCO melt-textured bulks made by Single-Direction Melt Growth method

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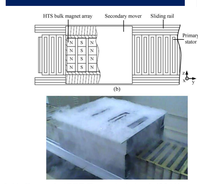
Backgrounds

REBCO melt growth (MG) bulks

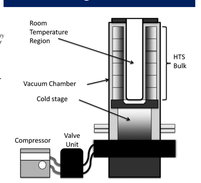
- Bi-axially oriented microstructures are formed during melt-growth from a seed.
- REBCO MG bulks can trap magnetic field as high as ~17.6 T due to large circulating currents. J. H. Durrel *et al.*, *SuST* (2014).
- REBCO bulks in various shapes are required for a variety of applications
- Reproducibility especially for preparation of large bulks should be improved for further practical applications.

Linear synchronous motors with HTS bulks



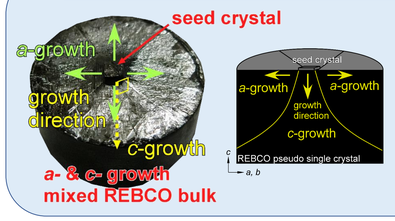
J. X. Jin *et al.*, *IEEE Trans. Ind. Appl.* (2011).

Desktop NMR with HTS ring-bulks



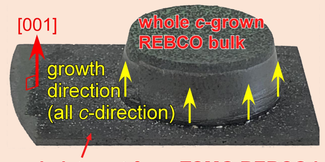
T. Nakamura *et al.*, *J. Magn. Reson.* (2015).

Top-Seeded Melt Growth (TSMG)



- Mixed *a*/*c*-growth regions leading to inhomogeneous B_t distributions
- Very long-time crystal growth needed especially for large bulks
- Quality of the bulks depending on the size and quality of seed crystals

Single-Direction Melt Growth (SDMG)



- Whole *c*-grown bulks obtained through one-direction melt growth
- Short growth-time independent of the diameter of the bulks
- Flexibility in shapes (rectangular, ring, *etc*)
- Recycling of seed plates leading to high reproducibility

T. Motoki *et al.*, *Appl. Phys. Express* (2020).

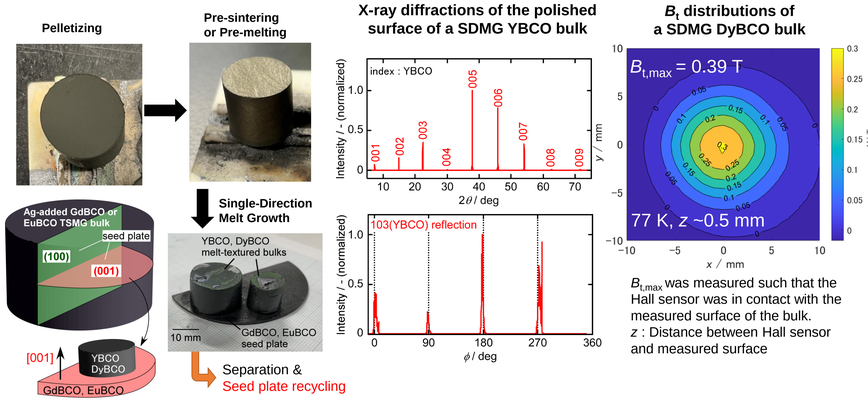
Motivation & Strategies

Preparation of YBCO and DyBCO bulks in various sizes and shapes was attempted using Single-Direction Melt Growth (SDMG) method using GdBCO and EuBCO seed plates, respectively.

- ☐ Investigation on crystallographic orientations for SDMG processed bulks.
- ☐ Evaluation of trapped field (B_t) distributions at 77 K for the prepared bulks including rectangular or ring-shaped bulks.
- ☐ Estimation of flowing current density inside the bulk from B_t distributions.

Results & Discussion

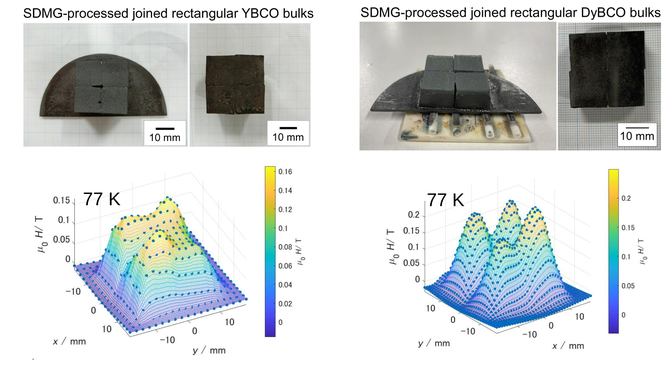
Preparation, Crystallographic orientation & Trapped field distributions of cylindrical SDMG bulk



$B_{t,max}$ was measured such that the Hall sensor was in contact with the measured surface of the bulk.
z : Distance between Hall sensor and measured surface

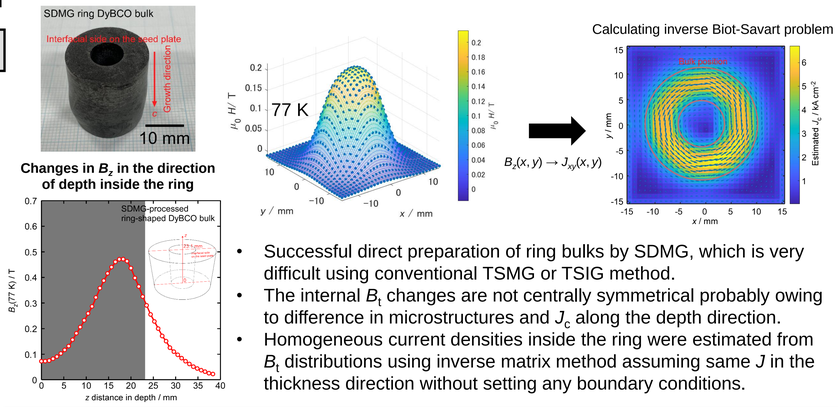
- Typical glossy appearance of melt-textured bulks observed after SDMG
- Successful preparation of bi-axially oriented REBCO bulks using SDMG method (YBCO on GdBCO & DyBCO on EuBCO)
- Circular B_t distributions reflecting microstructure consisting of whole *c*-growth region

Preparation & Trapped field distributions of joined rectangular YBCO, DyBCO SDMG bulks



- Mechanically joined large rectangular bulks (~27 × 27 × 7^t mm^3) were successfully obtained during SDMG by simply installing rectangular bulks adjacent to each other.
- B_t distributions reflecting rectangular bulk-shapes
- Partial superconducting joints achieved between interfaces

Trapped field distributions & Estimated current distributions of ring-shaped SDMG bulks



- Successful direct preparation of ring bulks by SDMG, which is very difficult using conventional TSMG or TSIG method.
- The internal B_t changes are not centrally symmetrical probably owing to difference in microstructures and J_c along the depth direction.
- Homogeneous current densities inside the ring were estimated from B_t distributions using inverse matrix method assuming same *J* in the thickness direction without setting any boundary conditions.

Experimental

Starting powder from TEP
Y123 : Y211 = 7 : 3 (mol)
Dy123 : Dy211 = 7 : 3 (mol)

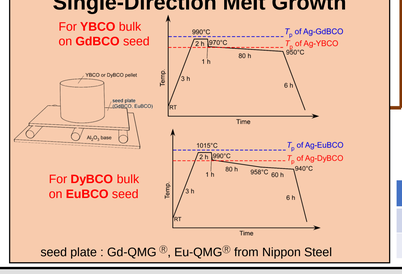
Calcination (850°C, 24 h, in air)

← Mixture of Pt 0.1 wt%, Ag_2O 10 wt%

Pelletizing (cylinder, ring, *etc*),
& **Uniaxial pressing** (~100 MPa)

Pre-sintering (940°C, 24 h, in air) for YBCO
Pre-melting (1035°C, 2 h, in air) for DyBCO

Single-Direction Melt Growth



seed plate : Gd-QMG®, Eu-QMG® from Nippon Steel

REBCO melt textured bulks

Separation & Decarbonation
(500°C, 24 h under O_2 flow)

Reductive post annealing
(850°C, 12 h under 1%O_2/Ar flow)
Only for **DyBCO** bulks

O_2 annealing
YBCO (400°C, >200 h under O_2 flow)
DyBCO(425°C, >200 h under O_2 flow)

Evaluation
XRD
Trapped field(B_t) measurements
(FCM @77 K, magnetization : 1 T)

Peritectic temperatures (T_p) of RE123 with different RE elements

RE	Nd	Eu	Gd	Dy	Y
T_p / °C	1090	1050	1030	1010	1000
T_p (Ag-added)	~1070	~1030	~1010	~990	~980

Conclusions

Preparation of REBCO bulks in various sizes and shapes was attempted using Single-Direction Melt Growth (SDMG) method.

- Homogeneous REBCO bulks in various shapes, including ring-shapes, were successfully obtained directly from the seed plate.
- Partial superconducting joints were achieved between interfaces during SDMG by simply installing bulks adjacent to each other.

SDMG is promising in preparation of bulks in a short time regardless of the bulk-diameters with high reproducibility.

Acknowledgments

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