Current Progress in HTS Bulks and Materials for Industrial Applications

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INTRODUCTION

- Czech private limited company with market presence since 1996
- Manufacturer of HTS materials and bulks
- Own extensive R&D and continuous innovation
- Cooperation with major academical organizations worldwide
- Products supplied to 45 countries
FROM RAW MATERIALS TO BULKS

5,000+ bulks produced in 2022
BATCH PRODUCTION
multi-step QC, ISO Certified
REBCO BULKS

- YBCO, GdBCO/Ag, EuBCO/Ag
- Simple & complex shapes
- Disks Ø up to 100 mm
- Std Btr up to 2.5 T @ 77 K
- Levitation Force up to 1,000 N
REBCO Bulks for Bearings
Kinetic Battery
Based on Boeing Flywheel Project

- Modular system to scale up or down to shifting local power needs
- Single flywheel power 167 kW, capacity 5 kWh, Weight 2.5 t
- Compact & mobile: 10 flywheels for 1MW bankable in 20ft container
- Very low energy losses (<0.1% per hour)
- +350,000 cycles with at least 20 years of operation
- Ideal for peak shaving frequent high-power peaks
- Shock breaker for microgrids
QuinteQ
Market Focus

Military

Military and civilian microgrids, directed energy systems

E-Transport

E-logistics - metro/train, construction, ports/cranes, fast-charging

Civilian off-grid

Ports, cranes & mines
QuinteQ
Flywheel Energy Storage System
PROJECT
Showcasing a scalable, hybrid energy storage solution utilizing existing plant infrastructure,

Hydroxide salt energy storage for combined heat and power production for long-duration grid-scale energy storage by HYME

Battery storage consisting of used car batteries from PLS Energy Systems

Flywheel from QuinteQ for short duration energy storage.

Tied together by a hybrid energy management system, to balance the grid and provide stored energy when needed.

The project in Rønne, Bornholm.
Applications: REVTERRA FLYWHEEL

Initial market application: rapid EV charging

modular 400kW/100kWh base unit, with the option for expanding installations
Applications:
REBCO Rings for Bulk Based MRI

EuBCO/Ag Rings
OD 64, h 13 mm

Z-scans through the ring bore persistent current 32 kA at 77K

2D map trapped field shows high homogeneity

Ring 64-32 (2)
I = 32.2 kA
Jc = 15480 A/cm²
r = 23.35 mm
Applications:
GdBCO/Ag Bulks for HTS Undulators

Undulators: accelerator based light sources

Undulators employ successive static magnetic fields to make passing electrons oscillate, resulting in the emission of highly concentrated radiation. The emitted radiation is channeled through beamlines for experiments across different scientific domains.

State of the art:
Permanent magnets
Conventional superconductors

Challenge: HTS?
Applications:
GdBCO/Ag Bulks for HTS Undulators

HTS UNDULATOR AIM: to reduce the period length and increase the magnetic field beyond today capability of existing undulators (2T+??)

2023 Status: High magnetic field >2T demonstrated in a short sample staggered array undulator made of GdBCO bulks exceeding existing tech.
Applications:
GdBCC/Ag Bulks for HTS Undulators

Challenges For Undulator Bulks:

- Maximum properties homogeneity is a must – minimum performance deviations required
- Micro-meter accuracy bulks cutting (EDM wire erosion) for shrink-fitting into a copper matrix
- Repeated QC (Btr mapping) during production, prior to cutting, after embedding
- New batch of CAN SDMG bulks to be tested in September
- Next step 1.0 m long prototype, will require a few hundred perfectly uniform bulks
Bi-2223 Bulks

Bi-2223 Magnetic Shields
Diameter up to 100 mm
Shield > 15 mT (77K)
Ideal for shielding SQUIDS

Bi-2223 Current Leads
New generation of current leads
Up to 2,000 A (77 K)
Used in high-field systems
Materials for production of HTS Wires

REBCO Granulates for PVD

Over 1 ton of material/year for established CC manufacturers

REBCO Targets for PLD

Targets up to 12” diameter,
Materials for production of HTS Wires

R&D of primary materials for CC manufacturers and startups

Custom matrix compositions
Thorough analyses

Various dopants
Individual approach

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2023. Invited presentation given at EUCAS 2023, Sept. 3-7, 2023, Bologna, Italy
CHALLENGES: REBCO Recycling

**TSMG overall growth failure rate:** a few % to tens of % depending on size

- may become important with increasing production volumes
- established method for chemical recycling of REBCO and Ag
- can easily be scaled up

SILVER RECYCLING

REBCO/Ag dissolution in nitric acid and subsequent selective precipitation resulting in pure metallic silver
CHALLENGES: REBCO Recycling

Adding 15 - 30% of recycled material...

...does not significantly impact levitation force of YBCO crystals.

...does not prevent single domain character of YBCO bulks.

(28 mm YBCO disks LF > 70 N)

15 % recycled

30 % recycled
SDMG – Single Direction Melt–Growth

- Developed by Dr. Motoki
  *Supercond. Sci. Technol.* **35** 09400 (2022)
- Novel method of crystal growth
- REBCO bulk is used as a seed
- Utilizes different $T_p$ of REBCO systems
- Entire bulk is grown in a single-direction

**Diagram:**
- Temperature vs. Time graph with key temperatures $T_p$, $T_m$, $T_s$, $\Delta T_p$, $\Delta T_s$, $\Delta T_6$.
- Pressed bulk with growth direction indicated.
- Seed-plate shown.

**Images:**
- $\varnothing$ 32 mm ring
- $\varnothing$ 66 mm
- $\varnothing$ 35 mm

**Material:**
- GdBCO + 10 % $\text{Ag}_2\text{O}$
SDMG – Single Direction Melt–Growth

**ADVANTAGES**
- Improved properties homogeneity
- Decoupling of diameter and growth time
- Robust growth with high yields
- Allows growth of complex shapes

**CHALLENGES**
- Requires bulks as seeds (difficult for REBCO systems with high $T_p$)
- Still needs further tuning
Challenge: Additive REBCO Manufacturing

- SLM – selective laser melting – 3D printing technique used in metallurgy
- Can likely be used for REBCO due to its unique properties
- Preparation of dense body by SLM and growth via SDMG
- Developed spreadable REBCO powder
- Singletracks currently underway
CHALLENGES: Scaling up

Driving progress: Where Chemistry Meets Capacity

Precursors: plan to transfer to high-capacity equipment available in market for advanced chemicals, tests underway

Bulks: ongoing batch production in foreseeable future, larger batches – larger furnaces –, yield increase (SDMG), continuous production not expected

REBCO Granulates: successful industrial trials completed, transition from lab-scale to advanced technology platform
From Laboratory Benchmarks To Industrial Innovations

THANK YOU!