From HTS Material Optimization to System Manufacturing – First Commercial FCLs from Nexans SuperConductors

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50351 Hürth, Germany
• Introduction
• Material aspects of Bi-2212 (bulk and precursor)
• FCL systems
  – Function
  – System manufacturing
  – Projects realized and first field tests
• New projects in progress and new installation planned
• Conclusions
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Materials – Components - Systems

From R&D to systems
10'1987
01'1995
01'1998
05'1998
10'1999
10'2000

Hoechst
ZF Frankfurt Höchst and GBA Knapsack

Hoechst
Corporate Research & Technology

HOECHST RESEARCH & TECHNOLOGY

Aventis
Research & Technologies

Alcatel High Temperature Superconductors

chemistry
physics
material sc.
electrical eng.
mechanical eng.

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Nexans SuperConductors in new premises 2010

Office building and assembly hall

bldg. 2728

- Assembly of Fault Current Limiter systems
- Building height allowing crane hook of 7 m
- Optimisation of the production

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Nexans SuperConductors
HTS system provider

Office building and assembly hall

Address remained unchanged:
Chemiepark Knapsack, D-50351 Hürth

Workshop and test field

Production annex

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Materials and conductor types for industrial HTS applications

**Bi-2212/ Bi-2223 tape**  
1st generation

**Y-123 cc-tape**  
2nd generation

**Bi-2212 bulk**

**Y-123 bulk**

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Production of HTS-bulk

BSCCO-2212 Melt Cast Processing

Highly efficient and very flexible process

Melting

Mixing

Casting

Annealing

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Microstructure of Melt Cast Processed BSCCO-2212

- Highly non-uniform **as-cast** microstructure
  (governed by directional solidification under conditions of thermal gradient)

  /* 5 mm diameter rod */

- Rather uniform **final** microstructure
  (with rather good quality Bi-2212 phase)
Nanostructure adjusted for high Jc and Resistivity

No long-range texture

- $J_c(77 \, K, \text{ sf}) \sim 1 \, \text{kA/cm}^2$
- $J_c(4.2 \, K, \text{ sf}) \sim 50 \, \text{kA/cm}^2$

- High resistivity
  - $\rho(300 \, K) \sim 5 \, \text{m}\Omega\cdot\text{cm}$

(Left) A high-angle GB with the tilt angle reduced from 45 to 17° due to lattice plane bending and (Right) a GB free bent grain (bending due to array of edge dislocations). TEM study by F. Kametani (NHMFL, Tallahassee) [compiled from D.C. Larbalestier et al, presentation at WAMSDOO 2008].

MCP Bulk BSCCO-2212 very suitable for FCL applications

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Equilibrium precursor*

... designed for Partial Melt Processing of Ag-sheathed conductors

- same phase composition and particle size at RT and close to melting
- controlled particle size $d_{50} \sim 1-1.5 \mu m$
- $< 100$ ppm C (in a granular material)
- sharpest melting transition

Standard cation stoichiometry:

$\text{Bi}^{2+}1.16(3)\text{Sr}^{2+}1.94(3)\text{Ca}^{2+}0.90(3)\text{Cu}^{2+}2.00(3)$

1 to 3 wt.% second phases

Highest reproducibility
Optimization of various wires (2010)
J. Jiang, E.E. Hellstrom, D.C. Larbalestier (ASC, NHFML)

- NG = Nexans granulate
- NStd = Nexans standard powder
- SCI = SCI Engineered Materials

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**HTS High-Field Insert Magnets**

K Marken, S. Heung, Z Melhem (OST), H Wejers (NHFML),

2003 (NHFML, OST)
First 25T SC Coil:
20 T with LTS +
5T with Bi2212

2008 (22 T), 2010 (22.5 T):
Latest Developments in High Filed Magnets:

\[
22.5T = 20T \text{ with LTS} + \\
2.5T \text{ with Bi2212}
\]

**Rutherford Cable**

S C Kim (Nexans Korea), S-S Oh (KERI)

2008:
\(30\) strands Rutherford cable – Ic > 4,000 A @4.2K

**Dipole Magnet for VHFSMC**

A Godeke (LBNL), Y. Huang (OST),

2009, 2010:
Dipole SC-08 Magnet with
Ic ~ 2600 A (4.2 K, sf)

Wind @ LBNL + React @ OST

**NSC Bi-2212 precursor inside**
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# Function of the FCL

<table>
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<th>current</th>
<th>normal operation</th>
<th>short-circuit</th>
<th>recovery</th>
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**Operating behaviour of the FCL**

- **ultrafast**
  reacts in 1-2 milliseconds

- **automatic**
  no external trigger necessary, self-recovering

- **wear-free**
  service only for cooling system

Superconductor Fault Current Limiters are intrinsically safe!
12-100 (ASL 1)  
first commercial system  
Field tested for ~8 months

12-800 (Vattenfall)  
first system in a power station  
Field tested Nov. 2009- Dec. 2010

12-400 (ASL 2)  
second system for UK (bifilar)  
Presently under installation
Project 1: 12-100 Realisation

• first FCL-System realised by NSC
• first commercial system worldwide
ASL, Newcastle
ENW, Bamber Bridge

Live on grid
10-2009 to 06-2010

Project 1: 12-100
Field test

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Project 2: Vattenfall Brown Coal Power Plant

Block Q in Boxberg
Power to the consumer
Power to the consumer
Auxiliary Power
Not limited short circuit currents

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High Short Circuit Currents
- high mechanical and thermal forces

No “fuses” on the MV power distribution level
- equipment and grid must be short-circuit proof
- high investment for equipment “oversizing”
From metal oxide powder to HTS-components

Melt Cast Process
Nexans proprietary process

BiSrCaCuO powder

BSCCO-2212 tubes

Fault Current Limiter Components

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**Connection for adaptation**
- **Current** in parallel
- **Voltage** in series

**Basic design of the FCL**

- Fault Current Limiter connected in series with the grid
- Current and voltage adjustable by modular construction

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Nexans is mastering the full chain.
High voltage and high current testing of complete FCL-system

Testing scheme:
• 75 kV lighting impulse
• 28 kV withstand voltage (1 min)

• 63 kA (peak) maximum
• 3-phase full loads (4 shots)
Location in Boxberg power plant

Standort im KW Boxberg

Standort:
Am Brecherturm Y 4UEF der Bekohlung für Block Q und R.
First FCL worldwide in a power plant

- Installation 10/ 2009
- Commissioning 02.11.2009
- End of field-test 12/ 2010
- second field-test starts IV/ 2011

- Significant savings for extension and new construction
- Improved safety for personnel and equipment

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Project 3: 12-400 for ASL

Customer has ordered second system!

Test at IPH

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Project 3: 12-400 for ASL

In UK around 270 substations (MV up to 33 kV) are at or above max. rating

Ainsworth Lane (Scottish Power)
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New developments: FCL systems based on cc-tape

12-600 (ENSYSTROB)
first MV system with cc-tape
This project has received funding from German government under grant 03KP102A

24-1000 (ECCOFLOW)
first system for two different customers
This project has received funding from the European Union Seventh Framework Program (FP7/2007-2013) under grant agreement No. 241285
Nexans and 13 European partners have reached an EU-project: ECCOFLOW cc-tape based FCL 24-1000

- 15 partners involved
- 5 utilities
- Coordinated by Nexans

First multipurpose system for two sites and applications
Project 24-1000 ECCOFLOW  
1st site for installation

Palma de Mallorca

High voltage
transformer feeder
FCL
busbar coupler
Medium voltage

Juan de Dios

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Project 24-1000 ECCOFLOW
2nd site for installation

VSE grid
Košice, Slovakia

Available space 6,5 x 15 m

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110-kV-substation (suburban area)

Conventional 110-kV-Cable

40 MVA

10-kV-substation (city center)

110-kV-substation (suburban area)

40 MVA

10-kV-HTS cable

10-kV-substation (city center)

Supply of city center by MV HTS cable

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Study showed project is
• technically feasible
• economically reasonable
Possible start 06-2011
First HTS cable with stand alone FCL
Conclusions

• **Full chain mastered from production of HTS material to final FCL system (for bulk)**

• **First commercial FCL systems realized** (w/o any public funding)

• **Successful grid operations also with the first HTS system in a power station worldwide**

• **Market entry with bulk already achieved**

• **New development projects started**
  → based on cc-tape
  → multipurpose device
  → new solutions for urban areas
First FCL worldwide in a power plant

Power safety at its best

Thank you for listening!

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