Thermal and mechanical properties of impregnation materials for HTS cables and coils

N. Bagrets, S Otten, K. -P. Weiss, A. Kario, W. Goldacker

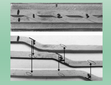
Institute for Technical Physics, Karlsruhe Institute of Technology

Institute for Technical Physics (ITEP)
Karlsruhe Institute of Technology (KIT)

M3PoB

Motivation

- Stress concentration on the tape edges in Roebel cable in HTS magnets can become problematic at stress levels caused by Lorentz forces



Disassembled Roebel cable after applying transverse pressure of 52MPa. Critical current degradation by more than 20% was observed
Uglietti *et al.* Superconductor Science and Technology. 2013 **26.7** p. 074002

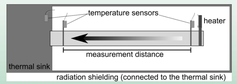
- Mechanical reinforcement of cable is needed to reduce stress concentration and critical current degradation. Impregnation with proper resin is one of the solutions for mechanical reinforcement.
- Impregnating resin is needed to fill the voids in the cables with a thermal expansion as close as possible to the cable material to prevent degradation of *RE*BCO tapes during cool down, and if possible with increased thermal conductivity for thermal stabilization of *RE*BCO tapes

Materials

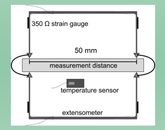
	Viscosity [Pa s]/ Processing temperature	Filler	Filling ratio [wt%]	Epoxy/Product name
	Electrically conductive fillers			
epoxy+silver	20/20 °C	Silver	60-80	Duralco 125
epoxy+graphite	50/20 °C	Graphite	50-60	Duralco 127
	Electrically insulating fillers			
epoxy	<0.2/40 °C			Araldite MY750/ Aradur HY5922
epoxy+silica 60	<4.5/80 °C	Silbond FW600 EST	60	Araldite CY5538/ Aradur HY5571-1
epoxy+silica 50	<5/80 °C	Silbond FW600 EST	50	Araldite CY5537/ Aradur HY5571s-1
epoxy+Al(OH)$_3$	0.7/60 °C	Al(OH)$_3$	56	Araldite CW5730N/ Aradur HY5731

Testing equipment

Thermal conductivity 4K - RT



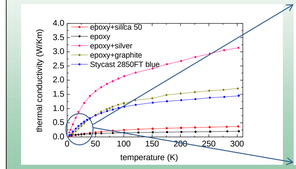
Thermal expansion 4.5K - RT

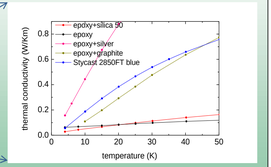


Tensile tests 4.2K, 77K, RT

Measurement results

Thermal conductivity 4K - RT





- Adding filler to epoxy increases thermal conductivity at RT and 77K
- At 4K effect of fillers does not show clear trend. Thermal conductivity is low and similar for all resins

Thermal expansion 4.5K - RT

Material	TE RT-77 K %	TE RT-4.5K %
epoxy+silver	-0.96	-1.04
epoxy+graphite	-0.53	-0.58
epoxy	-1.04	-1.15
epoxy+silica 60	-0.51	-0.60
epoxy+silica 50	-0.61	-0.67
epoxy+Al(OH)$_3$	-1.02	-1.11
Stycast® 2850FT	-0.43	-0.49
*RE*BCO tape	-0.25	-0.26

Testing results: tensile tests on resins at 4.2K, 77K, and RT

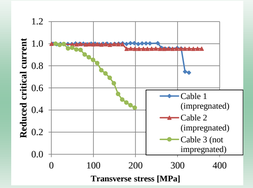
Material	Temperature K	Young´s modulus GPa	$R_{p0.1}$ MPa	Ultimate strength MPa
epoxy	RT	3.06	38	57.6
epoxy	77 K	6.67	125	149
epoxy	4.2 K	7.28	156	101
epoxy+silica 50	RT	6.91	48	66.4
epoxy+silica 50	77 K	13.92	-	177
epoxy+silica 50	4.2 K	15.33	-	158

- Adding silica filler to epoxy increases Young´s modulus approx. twice
- Ultimate strength is higher for filled resin than that for unfilled for all temperatures

⇨ Dispersion hardening effect from adding fillers is observed

Conclusions and outlook

- Adding fillers to epoxies decreases thermal expansion which matches better to *RE*BCO tape thermal expansion
- Fillers increase thermal conductivity at RT and 77K. At 4K this effect is not pronounced
- Enhancement of the transverse stress limit at the impregnated cable was shown. Still current reduction in cable was observed, trials on cable impregnation avoiding current reduction is ongoing
- Dispersion hardening effect from adding fillers is observed from mechanical tests



Otten S *et al.* 2015, Superconductor Science and Technology. **28** 065014