LNP-1

Laying of the superconducting feeder cable along railway line

*Masaru Tomita[1,2], Yusuke Fukumoto[2], Tomoyuki Akasaka[2], Kenji Suzuki[2], Atsushi Ishihara[2], Yusuke Kobayashi[2]

Research & Development Promotion Division, Railway Technical Research Institute, 2-8-38 Hikari-cho, Kokubunji-shi, Tokyo 185-8540, Japan[1]
Applied Superconductivity Laboratory, Materials Technology Division, Railway Technical Research Institute, 2-8-38 Hikari-cho, Kokubunji-shi, Tokyo 185-8540, Japan[2]

The superconducting feeder cable shrinks in cooling process from the room temperature to temperature of liquid nitrogen. When a long length superconducting feeder cable is constructed in railway line, it is needed to consider as a measure against the cooling force. In this paper, it was considered a suitable laying method of superconducting feeder cable, and the manufactured 300-m class superconducting feeder cable was actually set up on the test track. After that, a x-ray radiograph was taken over the whole length of the cable after the construction of the cable, and there were no buckling and rupture points, so the laying method is suitable for this superconducting cable.

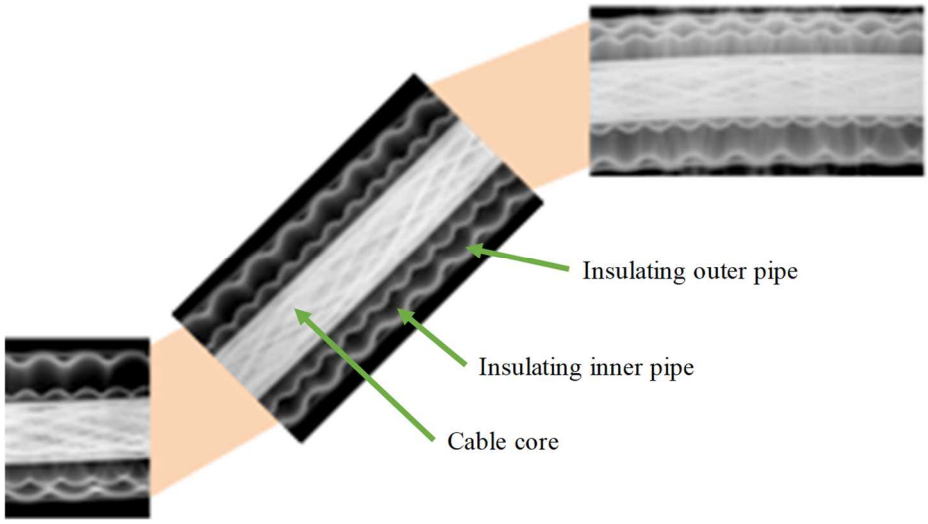


Fig. X-ray radiograph of the superconducting feeder cable

Keywords: superconducting feeder cable, X-ray radiography, laying method, cooling force

LNP-2

Dynamic performance of high temperature superconducting maglev system

*Li-Feng Zhao[1, 2], Lin-Bo Li[1, 2], Meng-Liang Yao[1, 2], Da-Jin Zhou[1, 2], Jing Jiang[1, 2], Yong Zhang[1, 2], Yong Zhao[1, 2]

Key Laboratory of Magnetic Suspension Technology and Maglev Vehicle, Ministry of Education, Chengdu, 610031, China[1]
Superconductivity and New Energy R&D Center, Southwest Jiaotong University, Chengdu, 610031, China[2]

we report the variation of force in the direction along guideway on high temperature superconducting (HTS) bulk running over permanent guideway with AC magnetic field at different speed. Larger variation of force is suggested to be caused by hysteresis loss at lower speed. While smaller variation of force observed at higher speed should be caused by eddy current loss.

Keywords: HTS maglev, YBCO bulk, AC magnetic field, Dynamic response

LNP-3

Realization and First Tests Results of the EuCARD 5.4-T REBCO Dipole Magnet

*P. Fazilleau[1], F.Borgnolutti[1], D. Bouziat[1], M. Durante[1], J.M. Gheller[1], F. Molinié[1], P. De Antoni[1]

CEA, Université Paris-Saclay, 91191 Gif-sur-Yvette, France[1]

A HTS dipole magnet relying on 12 mm REBCO tapes was built at CEA Saclay in 2016. Magnet studies had been started in the framework of the EuCARD High Field Magnet program and continued within a collaboration agreement between CEA-Saclay and Cern. The final goal is to generate 5.4 T at 4.2 K in the 13 T background field of FRESCA2 Nb3Sn dipole magnet. The HTS winding is made of three double-layer racetrack- type coils, wound from a stack of two double layer REBCO tapes, stabilized with beryllium copper ribbons. Before it is installed inside the aperture of FRESCA2, at CERN, the magnet has been tested at CEA-Saclay in standalone mode. After a brief recall of the magnet design, we will report on the magnet manufacturing, the screening current computations and the first powering tests results.

Keywords: Dipole, HTS, accelerators, screening currents

LNP-4

No-Insulation REBCO Pancake Coil with Stainless Steel Co-Winding Tape - Tests under High Resistive Background Field and High Current at 4.2 K

*T. Lécrevisse[1], T. Benkel[2, 3], A. Badel[3], P. Tixador[3], X. Chaud[2], P. Fazilleau[1]

CEA, Université Paris-Saclay, 91191 Gif-sur-Yvette, France[1]
Laboratoire National des Champs Magnétiques Intenses (LNCMI), CNRS, Univ. Grenoble Alpes, 38042 Grenoble, France[2]
University Grenoble Alpes/CNRS, G2ELab/ Institut Néel, 38042 Grenoble, France[3]

Following our ongoing work on the French NOUGAT project under the French National Research Agency funding, we have built and test a single pancake coil under very high background magnetic field. Like for the insert project, the pancake consists of a REBCO HTS tape co-wound with a stainless steel tape (Metal-as-Insulation (MI) winding way). The MI winding is inducing a significant turn to turn electrical resistance which helps to reduce the charging time delay. Despite this resistance, the self-protection feature of No-Insulation (NI) coils is still enable, thanks to the voltage limit of the power supply. Our coil experienced over hundred heater induced quenches without “significant” increase of its internal resistance. We have gathered stability and quench behavior data in the 0-17 T and 0-635 A/mm² ranges. We also present our very first experiments on the insert/outsert interaction in the case of a resistive magnet fault. We show that if self-protection of the MI winding is really effective in the case of a MI coil fault, a major issue comes from the outsert fault which induces a huge current inside the MI coil.

Keywords: REBCO Tape, No-Insulation coil, Metal as insulation coil, magnet interaction

LNP-5

NUMERICAL SIMULATION OF INSTABILITIES IN MAGNETIC VORTICES IN TYPE-II SUPERCONDUCTOR UNDER NON-UNIFORM MAGNETIC FIELDS USING TIME-DEPENDENT GINZBURG-LANDAU EQUATIONS

*Hasnain Mehdi Jafri[1], Xingqiao Ma[1], Congpeng Zhao[1], Houbing Huang[1], Zhuhong Liu[1]

Department of Physics, University of Science and Technology Beijing, Beijing 100083, P. R. China[1]

The complex Ginzburg–Landau equations are often encountered in physics and engineering applications, such as nonlinear transmission lines, solitons, and superconductivity. Various numerical methods have been developed for the solution of GL equations, which include finite difference method, finite element method and spectral method. In the present work, time-dependent Ginzburg-Landau equations were solved for cubic superconductor by finite difference method using staggered grid scheme under the influence of 1) Static magnetic field 2) oscillating magnetic field and 3) hybrid static and oscillating magnetic field. Carrier concentration, magnetization and energy distributions were studied as a function of variation in external magnetic field. Small steps and kinks in carrier concentration was observed at positions of entrance and leaving of a set of vortices, such small steps were also observed in superconducting energy and sample magnetization. Instability in interaction energy which can result in thermal quenching of superconductor was observed to be lower in hybrid field case, compared to that observed in purely oscillating field, while no such instability was observed in the case of static magnetic field. This effect is strongly related to the magnetic field experienced by the superconducting maglev vehicle on permanent magnet guideway with intrinsic defects.

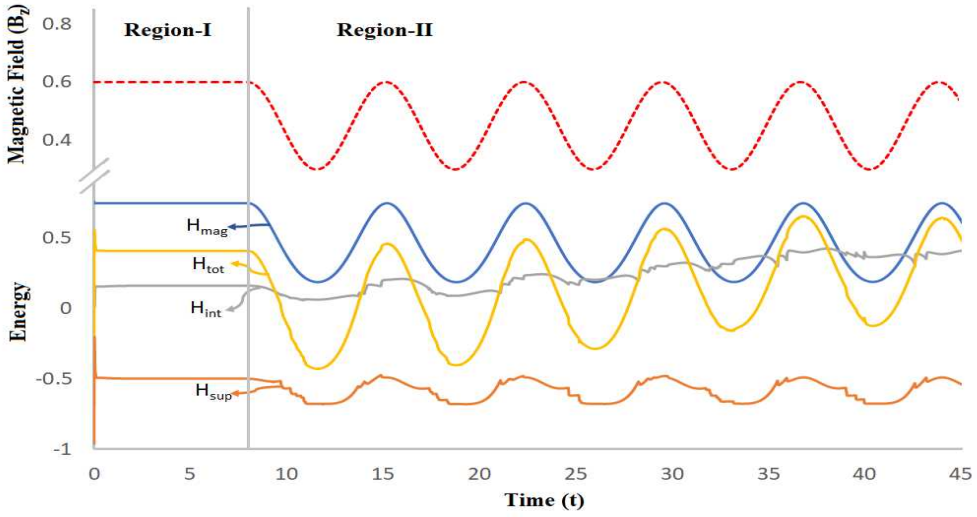


Fig. Temporal variation of average values of Magnetic, Superconducting, Interaction and total energies in static (region-I) and hybrid (region-II) magnetic fields (sample size $20\xi \times 20\xi \times 20\xi$, $\kappa=4$, $\sigma=1$ and $B_z = 0.45\,\kappa + 0.15\,\kappa \cos\theta$)

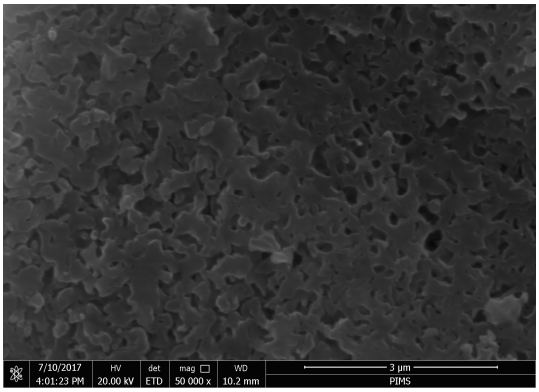
LNP-6

The improvement of MgB_2 prepared by hot-pressing sintering method with the MgB_4 precursor powder

*Hong Zhang[1], Yong Zhao[1,2], Yong Zhang[1]

Key Laboratory of Maglev Train and Maglev Technology of Ministry of Education, Superconductivity and New Energy R&D Center, Southwest Jiaotong University, Chengdu 610031, China[1]
School of Materials Science and Engineering, University of New South Wales, Sydney 2052, NSW, Australia[2]

To improve the density of MgB_2 is the key to improve the performance of the MgB_2. Hot pressing method can effectively improve the density of MgB_2. But the temperature up to the 1000 degrees, the density of MgB_2 increase has been very difficult. The volume shrinkage of magnesium and boron in the reaction process and brings holes which resulting in a decrease in density. If using MgB_4 precursor powder preparation, it can reduce the volume shrinkage rate, thereby reducing the porosity. In this paper, the MgB_4 precursor powder is carried out to prepare MgB_2 under the vacuum hot pressing conditions. Finally, the high-quality MgB_2 bulks are achieved with high density.



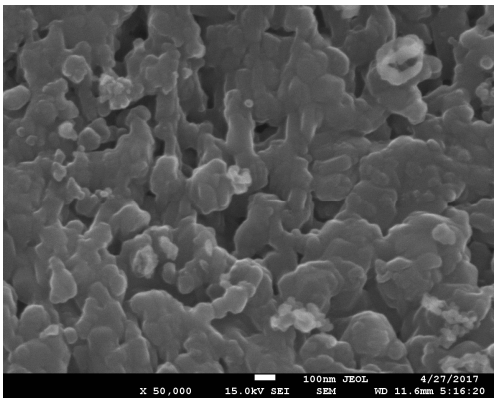
LNP-7

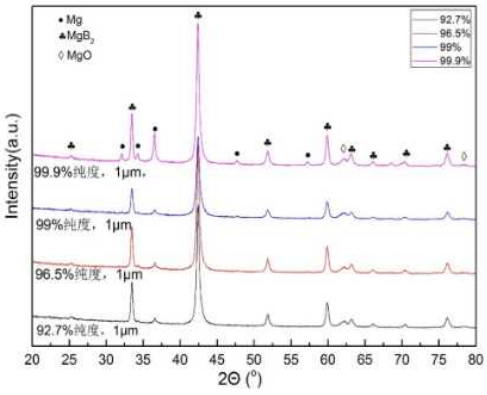
The effects of Mg precursor powder on the MgB_2 superconductor prepared by diffusion method

Yong Zhao[1,2], Hong Zhang[1], Yong Zhang[1]

Key Laboratory of Maglev Train and Maglev Technology of Ministry of Education, Superconductivity and New Energy R&D Center, Southwest Jiaotong University, Chengdu 610031, China[1]
School of Materials Science and Engineering, University of New South Wales, Sydney 2052, NSW, Australia[2]

The diffusion method can effectively inhibit the formation of MgO into the MgB_2 samples and improve the purity and density of the MgB_2 superconductors. Therefore, in this paper, the MgB_2 superconducting bulks are prepared by diffusion method to improve the MgB_2 application performance. The precursor B powders are pressed into bulks and the excess of Mg precursor powders with different purity and particle size are added into the iron pipe. Then the heat treatment is carried out under the pure argon atmosphere. Finally, the high-quality MgB_2 bulks are achieved with high density. The effects of precursor Mg powders with different purity and particle size on the MgB_2 superconductors were investigated. The experimental results show that the precursor Mg powder with low purity and large particle size are in favor of the preparation of high performance MgB_2 superconductor. Low purity and high size decrease the Mg powder cost. Therefore, this experiment provides a low cost to prepare MgB_2 superconductor with diffusion method.





LNP-8

Installation Design of 23kV 50MVA Class HTS Cable in S.Korea Grid

Young-jin Won[1], *Dong Cheol Koo[1], Joong-gu Jeon[1], Jae Hwan Song[1], Jin Bae NA[2], Young Woog Kim[2]

Korea Electric Power Corporation[1]
LS Cable&System[2]

As an initial step of this innovation, in September of 2016, KEPCO (Korea Power Electric Corporation) has launched world first commercial superconducting cable project, named **SSS** (**S**uperconducting **S**mart platform **S**tation in Korea) project, which will be not only the first commercial trial in grid but also a test bed for Smart Superconducting Platform in Korea.

Main target design of this project is installation of 23kV 50MVA class HTS cable system in power grid. Type of this HTS cable is 3 phase in One Cryostat which is remarkable way to transfer large power with low voltage and no electric magnetic field that means prevention of heating of other cores and metal sheath of cable. Total length of HTS cable between ShinGal and HeungDuk substations is slightly over 1km and it has 2 sets of normal joint box and 2 sets of termination. In this HTS cable system, mechanical stress during the cool-down and warm-up is major issue for increasing stability to set-up the HTS system and to connect existing power lines. To solve this issue of SSS project, we developed simulation program which used Equivalent Solving Method for reducing and predicting thermal contract force of HTS cable under the mechanical stress. Also, mechanical strength of metal sheath and copper wires as the former was measured by bending and tensile tests. Coefficient of elastic and thermal expansion according to various temperatures was calculated by these data. Analytical method was verifying by approximately 40m length HTS cable that has various installation condition such as using snake method at straight route in installation path. From the above procedures, we found that mechanical strength can calculate based on installation route in power gird

Keywords: 23kV 50MVA class HTS cable, 3 Phase in One Cryostat, snake method

LNP-9

Constitutive Equation of Multiferroic Bismuth Ferrite under the Framework of Onsager's Reciprocity Relations

*Upasana Panigrahi[1], Shuichi Torii[2]

Ph.D student in Advanced Technology, Kumamoto University, Kumamoto, Japan[1]
Department of Advanced Mechanical Systems, Kumamoto University, Kumamoto, Japan[2]

The rapid emergence in the field of multifunctional materials in the field of multi-ferrocity has sparked the experiments like molecular beam epitaxy, captivating fundamental physics and development of various propitious noble materials of thin films or multilayer. The magnetic control electricity or electricity control magnetism thin films or materials spurred the potential application in magneto-electronics or magnetoelectric effect. We have investigated the Onsager relations in the context of electromagnetic constitutive relations of linear, homogeneous multiferroic bismuth ferrite. The fundamentals of electrodynamics under coupled ferroic orders are elucidated along with balance laws of mass, linear momentum, angular momentum, energy and entropy and integrated with Maxwell's equations. Onsager's reciprocal relations and second law of thermodynamics are invoked to deduce bounds on the kinetic coefficients and to develop the thermodynamic admissible constitutive equations. The linear formulation is specialized for multiferroic bismuth ferrite for the application of plasma physics. Hitherto, it is envisioned in design implementation and characterisation of functional materials by optimising the material properties.

Keywords: Bismuth Ferrite, Multiferroic, Onsager`s reciprocal relations, high degree of ferroic orders

LNP-10

Upper critical fields and critical current densities characteristics of Nb_3Sn doped with fourth elements

*Yuya Tanabe[1], Tomohiro Yonenaka[1], Rina Yonezuka[1], Masaru Kiuchi[1], Edmund Soji Otabe[1], Teruo Matsushita[1], Yoshiyuki Monju[2], Taiji Mizuta[2], Kyoji Tachikawa[3,4], Kozo Osamura[5]

Kyushu Institute of Technology[1], Osaka Alloying Works[2], National Institute for Materials Science[3], Tokai University[4], Research Institute for Applied Sciences[5]

It is well known that adding a small amount of Titanium (Ti) to the bronze significantly increases the growth rate of the Nb_3Sn layer [1]. Furthermore, this addition improves the critical current density J_c and the upper critical field B_{c2} due to the refinement of crystal grains and the reduction of coherence length. On the other hand, the addition of Tantalum (Ta), Gallium (Ga) and Hafnium (Hf) also improves B_{c2}, while the addition of Magnesium (Mg) or Germanium (Ge) improves pining force density F_p.

In this study, the influence on B_{c2} and J_c when adding Mg, Hf, Ge, Ga, and Ta elements to bronze as a forth element for Nb_3Sn (composition Cu-15Sn-0.3Ti) was investigated. The appropriate addition amount of each element will be clarified in the future.

The thermal diffusion treatment for generating Nb_3Sn was carried out at 700℃ for 50 hours and 100 hours. Table 1 shows the specifications of all samples. The size of the samples is approximately 4.0 mm length × 3.0 mm width × 0.40 mm thickness. A SQUID magnetometer was used to measure $B_{c2}(T)$ and J_c. The temperature dependence of B_{c2} was determined from the temperature dependence of DC susceptibility. The magnetic field dependence of J_c was obtained from DC magnetization measurement. For all measurements, the magnetic field was applied perpendicular to the wide surface of the sample.

Table 2 shows the results of evaluating $B_{c2}(0)$ at 0 K using the WHH theory [2] from the temperature dependence of B_{c2} at 12–18 K. Overall, B_{c2} is higher in 100 h than in 50 h of heat treatment time. In addition, the difference in B_{c2} is largest in samples with added Mg for 50 h, but 100 h for those with Hf and Ta. On the other hand, the addition of Ga yielded the lowest B_{c2} in this measurement.

Figure 1 shows the magnetic field dependence of J_c normalized by the value in self-field at 14 K for 100 h samples. The magnetic field dependence of J_c was excellent in samples containing Hf, Ta and Mg. On the other hand, the samples with added Ga showed the worst magnetic field dependence on J_c among the samples measured in this measurement. However, since Ga is easily incorporated into Nb_3Sn [3], excessive Ga added is considered to be the cause of J_c deterioration.

[1] K. Tachikawa, H. Sekine, Y. Iijima: J. Appl. Phys. **53** (1982) 5354–5356; [2] E. Helfand *et. al.*: Phys. Rev. B **23** (1964) 686–688; [3] K. Tachikawa *et. al.*: Abst. CSJ Conference, **94** (2017) 37

Table 1: Specifications of the Nb_3Sn

Composition (mass%)		50 h	100 h
Cu-15Sn-0.3Ti		ST-50	ST-100
	+0.5Mg	Mg-50	Mg-100
	+0.5Hf	Hf-50	Hf-100
	+0.05Ge	Ge-50	Ge-100
	+5Ga	Ga-50	Ga-100
	+0.08Ta	Ta-50	Ta-100

Table 2: Estimated $B_{c2}(0)$ in each samples by WHH theory.

	ST	Mg	Hf	Ge	Ga	Ta
50 h $B_{c2}(0)$ [T]	19.9	22.0	20.3	20.1	17.5	21.3
100 h $B_{c2}(0)$ [T]	22.4	23.5	25.9	23.1	20.7	25.3

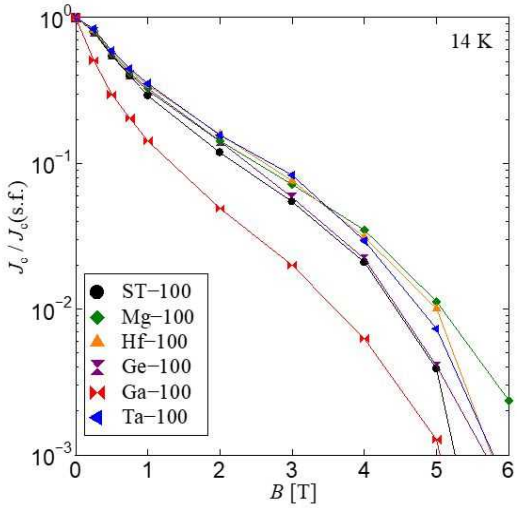


Fig. 1: Magnetic field dependence of J_c at 14 K for 100 h samples.

Keywords: Nb_3Sn, Element addition, Bronze process, Critical current density, Upper critical field

LNP-11

Novel Discovery of Nano Tubular $YBa_2Cu_3O_x$

*William Rieken[1], Atit Bhargava[1,2], Rie Horie[3], Jun Akimitsu[3], Hiroshi Daimon[1]

Graduate School of Materials Science, Nara Institute of Science and Technology, Ikoma, Nara 630-0192, Japan[1]
Scotch College Melbourne, Hawthorn VIC 3122, Australia[2]
Research Institute for Interdisciplinary Science, Okayama University, Okayama 700-8530, Japan[3]

Herein, we report the first known fabrication of the high temperature superconductor $YBa_2Cu_3O_x$ (YBCO) in the morphological form[1)] of nanorods and nanotubes[1,2)] by solution chemistry[3)]. Reagent grade oxides of Yttrium, Barium, and Copper in 1:2:3 stoichiometric proportions were dissolved in an acidic solution and upon precipitation, a fine-grained, less then 5nm, mixture was obtained. The precipitate was calcined at 773 K for 2 h, then subsequently converted to YBCO nanorods and nanotubes by heating to 1223 K in oxygen for 12 h. X-ray diffraction showed that the powder consisted of nanorods and nanotubes predominantly of the $YBa_2Cu_3O_x$ phase. A critical superconducting transition temperature T_c of 92 K was achieved in a critical magnetic field of 10 Oe, along with observing the Meissner effect.

The poster presents the novel discovery of nanotubular structures. Transmission electron microscope (TEM) and scanning electron microscope (SEM) images (Figures 1 and 2) reveal the tubular morphology of the structures. A significant finding is that the nanorods and nanotubes are superconducting without the need for further sintering or oxygenation, providing an avenue for the application of $YBa_2Cu_3O_x$ to substrates at room temperatures or direct use in the form of nanorods and nanotube powder.

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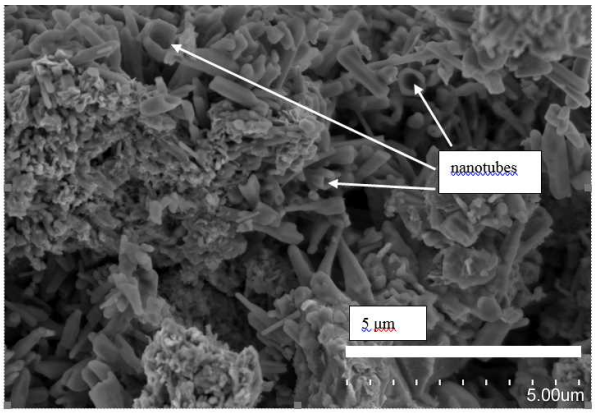

Figure 1: SEM image of superconducting nanorods and nanotubes showing nanotubes

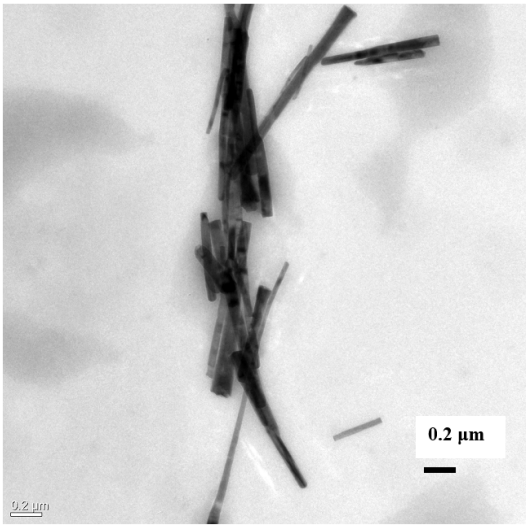

Figure 2: TEM image of superconducting nanorods and nanotubes showing thickness as little as 50 nm and lengths as large as several micrometers

LNP-12

A simplified white box model for real-time application to estimate the magnet temperature of superconducting tokamaks

*Dong Keun Oh[1], Sang-Hee Hahn[1]

National Fusion Research Institute, Daejeon, Korea[1]

As a minimalist model of physics-based magnet safety monitoring tool, a 0-D model of thermo-hydraulic quantities of the KSTAR PF magnets [1] is developed as a pessimistic temperature estimation for givren current scenarios. To check the feasibility of real-time application, we implement a fast routine using the multi-thread parallelization of hardware accelerator. To meet the performance, we attempt not only to simplify the ODE solver as a simpleRunge-Kutta step, but also to replace the functions of material property with the data tables in texture memory. Through these types of acceleration, it is achieved that 0.1 sec of real operation can be forecast within ~10 ms, which means the calculation is fast enough to monitor in advance of the actual change in the devices. Including the possibility of a gray-box model to take into account the convectional and diffusional couplings, the technical issues to implement the usable model are also discussed especially in terms of the operation of the plasma control system (PCS).

References:
[1] Dong Keun Oh, “KSTAR hotspot – a zero-dimensional model analysis code for the thermal behavior of the KSTAR PF magnets” technical document of NFRI (NFRI-2011-100001-0305-0389) written in Korean.