LN-1-INV

Accessing critical currents in large pulsed fields: challenges and opportunities

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Expanding non-linear transport (I-V) studies to magnetic fields above those accessible by DC magnets can bring valuable information on vortex pinning and phase diagram of superconductors. Very-high field all-superconducting and hybrid magnets make it technologically relevant to study vortex matter in this regime. However, pulsed magnetic fields reaching 100T in milliseconds impose technical and fundamental challenges that have prevented the realization of these studies. Here, we present a fast I-V DC technique that enables determination of the superconducting critical current in pulsed magnetic fields, beyond the reach of DC magnets.[1] We demonstrated this technique on standard and pinning enhanced $RE\mathrm{Ba_2Cu_3O_7}$ (RE = rare earth) on single crystal and metallic substrates with excellent agreement with DC field measurements.[1,2] The I-V characteristics change with the magnetic field rate. We capture this unexplored vortex physics through a model based on the broken symmetry of the vortex velocity profile produced by the applied current.[1] By measuring J_c at 65T, 4K, we are able to observe the end of the power-law regime with important implications to applications and fundaments of the change of pinning regime.[2]

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Keywords: pulsed magnetic fields, current voltage curves, critical current, REBCO

LNP-1

DESIGN AND MANUFACTURING STATUS OF SUPERCONDUCTING MAGNET FOR MULTI-PURPOSE DETECTOR AT NICA COLLIDER

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The main scientific project being created at the Joint Institute for Nuclear Research is Nuclotron-based Ion Collider fAcility (NICA). One of the main elements of this complex is a multi-purpose detector, created on the basis of a large superconducting solenoidal magnet with a diameter of 5.2 m. The magnet will operate at a temperature of 4.5 K and a nominal magnetic field of 0.5 T. This publication describes the parameters of the magnet, a description of its subsystems, as well as manufacturing status.

LNP-2

Complex Research of the Unclosed HTS Shield for Improving Homogeneity of the Magnetic Field

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Homogeneous magnetic fields are required in different applications. The resolution of MRI techniques depends on the quality of the magnetic field, as well as the efficiency of electron cooling systems used at particle accelerators. Unclosed magnetic shield made of superconducting tapes is able to nullify the radial component of a solenoidal magnetic field, forming the long region of the homogeneous magnetic field.
The shield is a lengthwise winding made from (Y)BCO tapes are wound along a carcass generatrix. Then it is positioned coaxially inside an electromagnet. The measurements were carried out under quasistationary conditions, magnetic fields up to 1 kG at 77K.
This poster discusses the design of the superconducting shield and presents experimental and numerical studies into the homogeneity of the magnetic field in solenoids with the superconducting shield.

LNP-3

First-cut Design of a No-Insulation All-REBCO 7 T Whole-body MRI Magnet

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As high temperature superconductor (HTS) magnets exhibit noble current-carrying abilities under high magnetic field while being capable of operations at cryogen free conditions, they could be possible candidates for the future use for main magnets of ultra-high field magnetic resonance imaging scanners (UHF-MRIs). With employment of the well-known no-insulation (NI) technique, strong magnetic fields may be achieved within relatively small volumes, which is an attractive trait for commercial MRI. In this paper, we present a first-cut design of a no-insulation HTS magnet that generates a center field of 7 T in a 800-mm room-temperature bore. The magnet consists of a stack of double-pancake coils wound with multi-width REBCO tapes. The so-called "inside-notch" winding configuration is adopted to generate a target field homogeneity of <10 ppm in 40 cm diameter spherical volume (DSV). This paper presents: (1) detailed design parameters of the magnet; (2) performance analyses with the intrinsic "NI-behaviors" considered; and (3) discussion on the options for active shielding.

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Keywords: HTS magnet, multi-width, no-insulation, ultra-high field MRI

LNP-4

Opportunities and Challenges of No-insulation Winding Technique for Stability Enhancement of Low Temperature Superconductor Magnet

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The no-insulation (NI) winding technique for low temperature superconductor (LTS) magnet was proposed a few decades ago. In early days, mainly due to the low stability margin of LTS, the NI technique was regarded to be unacceptable to LTS magnets. Recently, multiple variations of the NI technique such as partial-insulation, metal-clad insulation, metal-co-wound and electrically-conductive epoxy resin were proposed, which led to an expectation to use those innovative winding methods to substantially improve stability margin of LTS magnets. This paper presents an analytic study on applying the NI (or its variations) technique to various LTS magnets. Stability margin and minimum quench energies are compared in various types of LTS coils with and without the *insulation*. Discussions on new opportunities and potential pitfalls are also provided in details.

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Keywords: Insulation, low temperature superconductor magnet, No-insulation, stability margin

LNP-5

Fabrication and Performance Evaluation of a 400-MHz 66-mm Bore All-REBCO Conduction-Cooled NMR Magnet

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In 2014, a project to develop a 400 MHz 66 mm high temperature superconductor Nuclear Magnetic Resonance (NMR) magnet was embarked with a team led by Korea Basic Science Institute in close international collaboration among the National High Magnetic Field Laboratory, Korea Institute of Machinery and Materials, Kunsan National University, Seoul National University, and SuNAM Co., Ltd. The magnet consists of a stack of 48 Double Pancake coils wound with the multi-width no-insulation winding technique. It operates under conduction-cooled environment at 20 K or lower to generate the target center field of 9.4 T at a nominal operating current of 187 A. To reduce temporal field drift and spatial field error due to screening current, the current sweep reversal method is adopted as a charging protocol. This paper presents design, construction, and operation results including passive and active shimming with the respective ferro and copper-coil shim sets.

Acknowledgement: This work was supported by the Korea Basic Science Institute (KBSI) grant D39611.

Keywords: Conduction-cooled, no-insulation, multi-width, REBCO

LNP-6

Simulation of Superconducting Coplanar Waveguides for Quantum Computing

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Superconducting circuit plays an important role in realization of a scalable quantum computer. Anomalous characteristics of superconductor such as extremely low surface losses and a single quantum state at the macroscopic level have been able to realize a scalable and programmable quantum computer. Unlike the ion trap architecture – another type of candidate for the realization of a quantum computer, Josephson junctions are mainly used as superconducting quantum bits (qubits) in superconducting quantum computing. Since the control and readout of multiple superconducting qubits are one of the most challenging issues to address, precise design and simulations of quantum IO systems are required. In particular, 3D cavities and 2D coplanar waveguides (CPW) are mainly employed to manipulate superconducting qubits using electromagnetic waves. In this paper, we present the performance simulation results of superconducting CPW and theoretical approaches for calculating anomalous characteristics of a superconductor.

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Keywords: Coplanar Waveguide, RF Resonator, Q-factor, Quantum Computing

LNP-7

Comparative Analysis of Superconducting Bulk-type magnet and Wire-type electromagnet Applicable to Mechanical DC Circuit Breakers

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The core technology of the DC grid system is to protect the system in the event of a transient and to cut-off the faults current in a trouble line, quickly.

We sat down to analyze to implement the DC breaking technology of mechanical DC circuit breaker on the faster and more safely. However, the mechanical DC circuit breakers have limitations on the opening speed and the components of the break contact. To solve this problem, we applied a superconducting electromagnet to a mechanical DC circuit breaker and proposed a method to reduce the DC Arc energy generated during the breaking operation.

In this paper, we proposed the application of superconducting bulk-type magnet and superconducting wire-type electromagnet to the conventional mechanical DC circuit breaker and analyzed the breaking characteristic. We designed a mechanical DC blocking contact, a superconducting bulk-type magnet, and a superconducting wire-type electromagnet through the Maxwell 3D program.

As a result, the Lorentz force was generated between the mechanical DC blocking contacts each applied the superconducting bulk-type magnet and wire-type electromagnets. The superconducting bulk-type magnets produced about 43.8 percent faster and the superconducting wire-type electromagnets produced about 87.2 percent faster DC Arc breaking speed.

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Keywords: Superconductivity, bulk-type magnet, Wire-type electromagnet, circuit breaker

LNP-8

Analysis of the Operating Characteristics of fault Current limited DC Circuit Breaker According to Superconducting Winding Type

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We proposed a current-limiting DC blocking technology with superconductors. In the case of the fault current, the fault current in the DC system is primarily limited by the superconductor. After that, the limited current is stably cut off by the DC circuit breaker.

In this paper, we analyzed the operating characteristics of DC circuit breaker according to the winding type of superconducting wire in the current-limiting part. The current-limit windings were selected as helical wire and spiral wire types. In the same length, spiral wires generate higher heat and magnetic fields than helical wires. However, spiral wire have higher inductance than helical wire rods, which delays the current limit. Therefore, in this paper, we analyzed the fault current limit rate, quench speed, and the DC breaker's breaking characteristics while changing the inductance according to the wire winding method. In addition, the power burden of each superconductor and DC circuit breaker was compared and analyzed. For simulation analysis, HFSS program was used to analyze the electromagnetic field analysis according to the winding type of the current-limit. Also, after the fault current is simulated using the EMTDC / PSCAD simulation, the breakdown behavior of the superconducting DC circuit breaker is analyzed.

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LNP-9

The Search of New Superconducting Materials in Ni – N and Ni –H Systems

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Fe–H and Fe–N systems are well known for their superconducting compounds with transition temperatures up to 50 K. Based on the affinity of iron and nickel atoms we suggested the existence of similar superconductors in Ni–N and Ni–H systems and undertook their theoretical search. The calculations on crystal structure prediction have been performed with evolutionary algorithms (USPEX package) and density functional theory (VASP) package at 100, 200, 300, and 400 GPa. As a result, several new candidates for superconducting materials have been revealed in the Ni-N system. During our investigation, the results on the Ni-H system have been published by Xi and co-authors [1]. The transition temperatures nickel hydrides do not exceed 1 K. In addition to Ni-H and Ni-N systems, we have also performed the search in Fe–H and Fe–N systems. Although no new perspective structures have been found in these systems, we will use them for comparison.

In the system Ni-N, which has not been investigated before, seven new stable structures have been found. The convex-hulls and corresponding sequences of phase transitions for this system are shown in Figure1. In nitrogen-reach part of the system which is more perspective for superconductors, the new structure NiN_2-*Pnnm* has been revealed. Found NiN_2-*Pnnm* is isostructural to FeN_2-*Pnnm*, which has a transition temperature of 4-8 K [2]. Our calculations of transition temperatures for NiN_2 are in progress, the results will be presented in Conference and in Proceedings.

Despite at ambient conditions nickel shows 2+, 3+, and 4+ valences, while iron only 2+ and 3+, at pressures above 100 GPa, both iron hydrides and iron nitrides are more reache in the number of phases in comparison with their nickel counterparts. However, this can be the consequence of a less thorough search in nickel compounds. In cases, when nickel hydrides or nitrides have the same stoichiometry they are usually isostructural.

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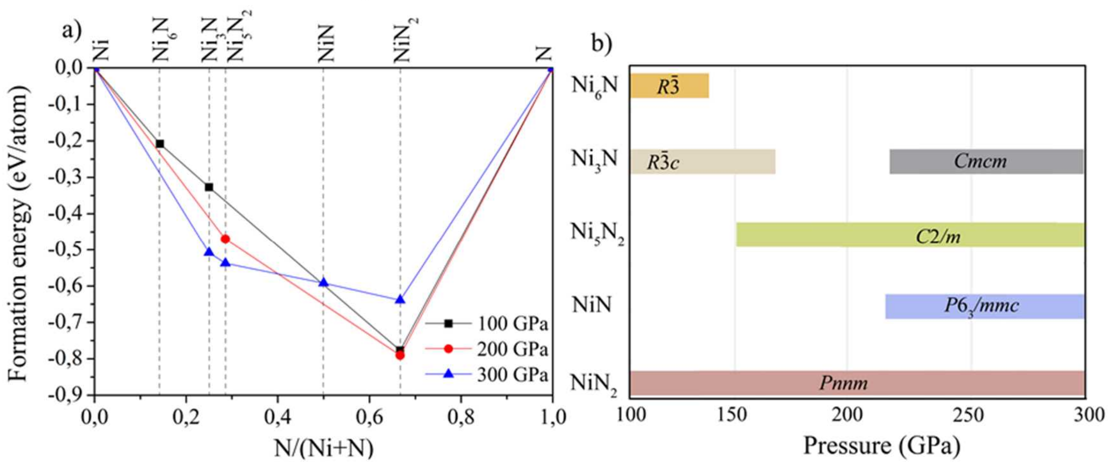

Figure 1. Convex hulls (a) and phase transitions (b) of Ni-N compounds.

Keywords: high-pressure, nitrides, crystal structure prediction, density dunctional theory