Superconductor Week

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IARPA Awards Contract to IBM to Build a Logical Qubit

IBM has been awarded a multi-year research grant by the U.S. Intelligence Advanced Research Projects Activity (IARPA) program to advance the building blocks for a universal quantum computer. The award is being funded under IARPA's Logical Qubits (LogiQ) program, which seeks to overcome the limitations of current quantum systems by building a logical qubit from a number of imperfect physical qubits.

IARPA initially solicited bids for the LogiQ Program last July. It is scheduled to begin on Feb. 1, 2016 and end by Jan. 31, 2021. In its solicitation, IARPA envisions that the success of the LogiQ program will require a multi-disciplinary approach to come up with new technical solutions that will better deal with the fragility of quantum information due to system imperfections, errors, and environmental influences. Logical qubit designs are seen as a potential means for packaging together qubits of high quality in a scalable form so that they can perform complex calculations in a controllable way, limiting the errors that can result from heat and electromagnetism.

IBM Scaling its Square Lattice of Four Qubits

Earlier this year, IBM scientists demonstrated a quantum circuit consisting of a square lattice of four superconducting qubits on a one-quarter square inch chip that detected and measured both bit-flip and phase-flip quantum errors (see *Superconductor Week*, Vol 29, No 5). Critical to IBM's success was the development of what its researchers call error-syndrome qubits, which are qubits that are entangled with the main data qubits performing the quantum computation. These error-syndrome qubits carry information about the collective parity, or the sign of the collective state, of the surrounding data qubits.

Since developing its square lattice of four superconducting qubits, IBM has been working on scaling its system to include more qubits. These efforts will continue under the LogiQ program.

"We are at a turning point where quantum computing is moving beyond theory and experimentation to engineering and applications," commented Arvind Krishna, Senior VP and Director of IBM Research. "Quantum computing promises to deliver exponentially more speed and power than achievable by today's most powerful computers. Investments and collaboration by government, industry, and academia are necessary to overcome the challenges towards building a universal quantum computer." ❍

LHC Luminosity Upgrade Shifts from Design to Construction Phase

The LHC luminosity upgrade project has advanced from the design to the construction phase. The project's advancement was marked by a gathering of over 230 scientists and engineers at CERN. CERN began the design phase of the LHC luminosity upgrade in 2011 (see *Superconductor Week*, Vol 25, No 24).

The design project was partly financed by the European Commission's FP7 Program. Completion of the design phase will now initiate bidding from industry for LHC ugrade contracts worth an estimated €300 million ($327 million) over the second half of this decade.

Luminosity to be Increased by Factor of Five to Ten

Luminosity gives a measure of the collision rate in a particle accelerator and therefore provides an indication of its performance. The LHC luminosity upgrade aims to increase the facility's luminosity by a factor of five to ten above its current design. It will therefore provide more accurate measurements of fundamental particles and enable physicists to observe rare processes that occur below the current sensitivity level of the LHC.

The project involves researchers from a number of institutions including the U.S. LHC Accelerator Research Program (LARP), CERN, CEA-Saclay, the French National Center for Scientific Research (CNRS), the Milan and Frascati divisions of the Italian Institute for Nuclear Physics (INFN), Rutherford Appleton Lab, the Cockcroft Institute, DESY, Ecole Polytechnique Federale de Lausanne (EPFL), Old Dominion University, and KEK.

In 2013, Oxford Instruments (OI) signed a contract with CERN as part of the high luminosity upgrade (see *Superconductor Week*, Vol 27, No 21). OI has worked with the magnet development team at CERN to industrialize the manufacturing of the Nb_3Sn dipole magnets. The company's focus is on process control and the refinement of manufacturing techniques.

Upgrade Involves Numerous SC Components

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Upgrading the LHC for higher luminosities requires new technologies in a range of fields including high field magnets, RF cavities, and electrical transfer lines. All of the new components are based on superconducting technology.

The upgrade will require about 20 to 30 tons of high-current grade Nb_3Sn with a J_c over 2500 A/mm^2 at 12 T for the high-field magnets. The project also involves the procurement of roughly 20 tons of MgB_2 or another HTS material for the superconducting links on the DC cable, as well as niobium sheets for the RF cavities.

LARP developed a powerful superconducting high-field quadrupole magnet that will play an important role in the LHC upgrade (see *Superconductor Week*, Vol 27, No 13). The magnet, dubbed HQ02a, is wound with Nb_3Sn cables.

Compared to the final-focus quadrupoles in place at the LHC, which are made with NbTi, HQ02a has a larger aperture and superconducting coils designed to operate at a higher magnetic field. LARP's HQ02a is designed like all LHC magnets to be cooled by superfluid helium.

Equipment to be Installed in 2018, 2022

The installation of the first four or six 11 T twin dipole Nb_3Sn magnets, part of the first crab cavities to be installed as part of the upgrade, and some superconducting links will occur in 2018 during a planned shutdown of the LHC. The superconducting links will help alleviate the effects of radiation on electronics and some power converters. The crab cavities will be used to orientate the beam before the collision to increase the length of the area where the beams overlap.

The remainder of the hardware will be installed during another planned LHC shutdown in 2022. This means that the construction of some 20 13 T quadrupole magnets, 6 to 10 11 T dipole magnets, eight crab cavity modules, and four 150 kA links must be ready and tested between 2019 and 2020. ❍

PSFC Developing Design for HTS ARC Fusion Reactor

Researchers at the Massachusetts Institute of Technology's (MIT) Plasma Science and Fusion Center (PSFC) have developed conceptual designs for an HTS magnetic confinement fusion (MCF) reactor that suggest that the use of HTS instead of LTS materials in the reactor could drastically increase their power generating capability. The designs suggest that a 10 T HTS MCF reactor the size of the Joint European Taurus (JET), the largest MCF tokamak currently in operation, could produce 500 MW of fusion power and net energy.

In MCF reactor designs, superconductors are used to generate the magnetic fields that confine the plasma. While increasing magnetic field strength offers potential ways to improve reactor performance, conventional LTS suffer dramatic drops in current carrying ability at high magnetic fields. The current design project is for the Affordable, Robust, and Compact (ARC) reactor and follows a previous study done by a student design class at MIT on a smaller device called VULCAN that was also based on HTS conductors.

Possible Funding for Project through Low Carbon Energy Initiative

"Until recently, our team at MIT was the only group in the U.S. looking at an HTS fusion reactor," said Joseph Minervini, Assistant Director of the PSFC. "Several people at the Princeton Plasma Physics Lab (PPPL) are now considering using HTS for a Fusion Nuclear Facility and for a possible large scale stellarator device.

"HTS for fusion reactors are now beginning to be studied at other labs around the world. The most serious work so far has been at the National Institute for Fusion Studies (NIFS) in Japan, that is looking at an HTS helical reactor made with segmented conductor sections. The ASIPP in Hefei, China is also starting to seriously look at an HTS reactor.

"In addition, many national base magnet technology programs have begun doing some small scale R&D on this topic. Over the past few years the fusion magnet community has self-organized an informal series of workshops called HTS4Fusion. Our most recent workshop was held in Italy this past September.

"We would definitely like to build a prototype device [based on the designs developed at MIT], but there are no plans for this under the present DOE-OFES base program. However, MIT has independently announced a new 5-year Low Carbon Energy Initiative which would solicit up to $300 million from industry and other benefactors to fund eight new research centers.

"Fusion Energy would be one of the new centers. The PSFC has also begun working on a smaller, faster concept than the ARC reactor for a prototype pilot plant called SPARC (Soon-as-Possible ARC)."

HTS Allows for Higher On-axis Magnetic Fields

HTS materials would be required to achieve 10 T on-axis toroidal magnetic fields in an MCF tokamak. Currently, the strongest tokamak designs reliant on LTS can achieve 6 T on-axis. High-T_c, high-magnetic-field superconductors can also make it possible to incorporate jointed magnetic coils into the reactor design, dramatically improving flexibility and ultimately maintainability for reactor systems.

"The idea is to be able to segment the toroidal field (TF) coils into a primary, main lower segment and an upper, removable segment," said Minervini. "If the conductor joints can be removed, then the top part of the tokamak can be removed allowing much easier access to remove the main nuclear components such as the vacuum vessel, breeding blanket, first wall, and divertor.

"It also provides for the first time the possibility of maintenance and repair of the large TF coils. If we operate the TF coils in the 20 to 25 K temperature range, the cryogenic heat load and refrigeration penalty caused by the resistive joint is not too high to allow acceptable overall power plant efficiency."

Magnetic Field Limited by Torus Structural Components

The 10 T field achievable using HTS components refers to the highest magnetic field at the electromagnetic coil, the key design feature for the magnet, and not the field at the plasma. Designs for the ARC reactor, for example, specify a peak field on coil of ~23 T, while magnetic field at the center of the plasma is 9.2 T. The ratio between these values is set by the geometry of the torus.

HTS opens a window for much higher magnetic fields since I_c does not degrade rapidly even at magnetic field values of 30 T or higher. For tokamak design, the field strength limits are primarily determined by the maximum allowable stresses in the structural components holding the magnet together and not by the intrinsic limits of the superconductors. The other limit to reducing size is neutronics, which can be partially addressed by a liquid immersion blanket enabled by the jointed superconductors.

"It seems that the limit to the magnetic field is not the HTS performance being as an all-HTS coil at 26.5 T has already been demonstrated and the National High Magnetic Field Lab (NHMFL) is working on a 32 T LTS/HTS hybrid magnet," said Minervini. "The limit will be structural based on the support material yield strength, elastic modulus, and strain limits in the superconductor.

"The ARC design is presently based on using 316 LN as the structural material, and this is sufficient to keep the stresses and strains within our usual allowable limits. However, the introduction of newer, high-strength, high-elastic modulus materials should allow one to push to even higher fields.

"From the magnet design point of view, the main limits include structure operating stresses and strains in the superconductor, how to handle the very high stored magnetic energy and quench detection and protection, and how to feasibly design and wind 50 to 100 kA multistage cables or conductors from a thin flat tape geometry. Cooling is always an issue, and if we do demountable joints the question is if we can make them reliable.

"The key challenge to producing much smaller fusion devices is to maintain the viability of the coils when the radial size of the neutron shielding blanket is trying to be smaller. This is linked to understanding the details of the radiation transport through the shield/blanket and the response of the HTS to the radiation field which we are now studying.

"We are looking at several options [for dealing with the stresses imposed by high magnetic fields]. One is to design a type of cable-in-conduit conductor. In the case of MIT we are looking at Twisted Stacked Tape Cables (TSTC), but we are also considering other options such as flat tape stacks in grooved plates.

"In most cases there will also be a structural steel case around the coil winding to take the majority of the stresses. We are fortunate that the HTS tape allows for winding the conductor in the already reacted state, and the inclusion of a high-strength substrate like Hastelloy helps a lot with the stress and local strain. In addition, the coils in ARC allow for a very high fraction (>90%) of the coil to be structural material (SS 316) which is allowed by the high I_c."

Designs use Commercially Available REBCO Tapes

Minervini added that the MIT team is currently planning to use REBCO material for the conductor: "We are basing the design on presently achievable J_c (B,T) with commercially available REBCO tapes from a variety of sources. For design purposes we always assume the magnetic field is parallel to the c-plane. This is in order to be conservative and to make sure we have sufficient operating margin everywhere.

"However, new results using REBCO are highly encouraging with respect to I_c performance at high field at different angles of the field to the tape. Further assessment is needed on what exactly are the right HTS materials, e.g. response to radiation fields, anisotropy of I_c, and so on."

HTS Allows for Optimized Plasma beta, Ion Gyroradius

A typical measure of fusion plasma physics performance is called plasma beta, which is the ratio of plasma pressure to magnetic field pressure. Achieving a very high beta, or generating the required plasma pressure with a low magnetic field, could help reduce the cost of the superconducting magnets used in a fusion reactor.

For this reason many visions of fusion reactors try to maximize plasma beta at moderate magnetic field strengths. Operation at higher beta and low magnetic field, however, generally pushes the plasma up against many performance and operation limits such as the beta limit, the kink/current limit, and the density limit, all of which tend to be unacceptable for the damage to interior components.

Another ratio, the size of the confined plasma compared to the ion gyroradius, also determines overall energy confinement and dictates plasma performance. The ion gyroradius is the radial size that helical path ions are forced to follow in the magnetic field.

Increasing magnetic field strength decreases the ion gyroradius, which allows a reduction in the size of the fusion device with no loss of performance. To first order by doubling the magnetic field strength allows a device at half the linear dimension, and thus 1/8th the volume. This approach also lowers beta and the plasma operates farther away from stability and operational limits.

Design to Reduce Size, Cost, and Improve Operation

"We do not want to use HTS or operate at higher field just for its own sake," added Minervini. "The design of a reactor at high field gives substantial advantages for the plasma physics performance with fusion power scaling as B to the 4th power. It allows one to make the reactor more compact, lower cost, and also able to operate in a more stable physics regime. If we can make demountable joints with REBCO then we can simplify the remote maintenance aspects of the device and improve the overall system reliability and uptime for efficient use as a baseline power plant.

"ARC is a conceptual design that we believe provided highly attractive features for a compact fusion pilot plant using HTS technology. We are presently pursuing different avenues of funding and research that allow us to address some of the integrated engineering issues on the HTS coils at small scale. Through our recently announced Low-Carbon Energy Research Center on Fusion we hope to engage a broad constituency in the private sector interested about the new possibilities in fusion and in other high-B applications." ❍

Grenoble Designs SFCL Linking Ship Power Systems

Researchers at Institute Neel of the French National Center for Scientific Research (CNRS) and Grenoble University are developing a superconducting fault current limiter (SFCL) for use with military ship DC high voltage power systems. The SFCL would enable the coupling of what are generally two separate power systems on ships, thereby providing stronger security and stability. The work has received financial support from the French Ministry of Defense (DGA) through the Insere HT project, which has the objective of studying the necessary elements for introducing all electric drives to battleships and submarines.

"'Electric ships, in which the drives are fully electric and supporting a high voltage onboard grid, already exist, but only for non-military applications or for military ships that are not combat vessels," said Arnaud Badel, Researcher at Institute Neel who is involved in the program. "Moreover, these grids are AC. Only preliminary studies have ever been conducted on DC high voltage networks for ships.

"Our research is a very preliminary and small-scale initiative to study fundamental technological elements that would allow the use of all-electric drives in combat ships and submarines. Electrical main drives mean much more power, therefore the need to increase voltage. Insere HT was more specifically oriented towards using a DC instead of an AC network.

"The technologies we are looking at are being considered for use in the next generation of ships or even the generation after that. The French Navy recently deployed a new generation of frigate and will soon deploy a new generation of attack submarine. A subsequent generation will not be deployed until after the lifetime of the current generation, therefore not for several decades."

Increased use of Electrical Drives Increases Fault Current Risk

The growing complexity of ship power requirements has made the use of all electrical drives more attractive. However, the higher demands placed on ship electrical grids increases the risk of fault currents.

Ship designers mitigate this risk by maintaining two separate port and starboard electricity grids, a common practice even for ships without all electric drives, so that a fault occurring on one side does not affect the other. However, using a dual system involves some duplication and limits operational efficiencies. Since costly and bulky equipment is generally not duplicated, a link is necessary between the two grids that is normally open but can be closed in the event of a fault.

“Warships in particular have a lot of extra power installed that is not used in normal operation,” said Badel. “The maximum speed is a lot faster than normal fuel-saving cruise speed.

“The generators are therefore largely overdesigned. The bridge normally allows the two drives to run on only one generator, but of course if there is a fault it can propagate on both sides and there can be a blackout.”

Grenoble Team Runs Simulations of SFCL Performance Onboard HVDC Ship Grid

The Grenoble team has proposed coupling the two systems with an SFCL. An SFCL would allow the grids to function as one system during normal operations and to be decoupled in the event of a fault.

“An SFCL allows meshed behaviour in normal operation but effectively disconnects the two sides in case of fault,” said Badel. “It is also reusable, which means that as soon as the fault is cleared operation of all other equipment can be restored automatically.”

The team has carried out simulations to study the operations of a shipboard SFCL, including how the use of such a device would impact the safety and protection of the electricity supply of an HVDC grid. They have assumed that DC electricity distribution is the emerging ship architecture, since it outperforms an AC solution. High voltage in the context of a ship’s grid means anything above 1.6 kV.

“The simulations show that an SFCL is feasible in an onboard HVDC grid,” said Badel. “It reacts well with the DC/DC converters, effectively preventing destruction of those in the event of major faults. Put differently, it allows the solid state elements to be designed to the operating current and not to the peak fault current, which is critical as these devices are bulky and costly.

“The simulations also demonstrate clearly that, as with other implementations, an SFCL can be vulnerable with regards to small overcurrents slightly above I_c. It is therefore mandatory to correctly identify the maximum possible peak current in the grid in normal operation and design the SFCL above that value.

“DC/DC and solid state devices react well in the case of small over currents, and the two technologies are in fact complementary. It would be ideal to design the SFCL to only react to severe faults and let the electronics handle the small over currents.”

Tests Conducted on Demonstration SFCL

The researchers conducted preliminary tests on a demonstration SFCL they developed that uses YBCO pancakes having several configurations with low or high inductances and series or parallel electrical connections. They are considering ratings of 500 A/1600 V or 1000 A/800 V.

“We studied the possibility of winding the SFCL so that is has a significant inductance, but the simulation indicated that such an inductance is not useful,” said Badel. “In the final design we used a low inductance winding.

“The design is purposely based on standard elementary pancakes with modest ratings. This reflects a major concern from our discussions with the military: the need to standardize so that a stock of multi-purpose spare pancakes can be maintained. The pancakes could be combined as needed to adapt to different grid requirements by connecting elements in series and/or in parallel.

“We only built one elementary pancake for the demonstrator with a rating of 500 A/800 V. It was tested in AC then in DC at a higher voltage that was close to but did not reach the nominal value for lack of an appropriate source. The current was however reduced by a factor of two as we used only one of the two tapes wound in parallel.

"To further test the demonstrator we are negotiating the possibility of using a high votlage test facility. We can also test it, however, with a power capacitor bank to receive a very large current during a short time. We are also currently investigating the development of such a capacitor bank and the matching switching unit to develop this test capability in house." ❍

Russian Team Designs 2G HTS Generator for Wind Turbines

Researchers from the Moscow Aviation Institute (MAI), the Scientific Research Institute of Electromechanics, and the Institute for High Energy Physics have developed and manufactured a 1 MW 2G HTS generator to be used in wind turbines. Experimental results demonstrated the potential for using 2G HTS windings in synchronous generators to increase the specific power up to 50 MW. The work received financial support from the Rosatom State Atomic Energy Corporation within the framework of the national Russian program "Superconducting Industry."

"The main objective of the program is to provide an innovative technical basis for improving electric power generation, distribution, and storage efficiency," commented Roman Ilyasov of MAI. "This will be achieved by developing and producing a wide range of electrical equipment units based on the newest technologies related to the use of unique materials, particularly HTS."

Specific objectives include the development of technologies for and production of 2G HTS tape of long lengths up to 1000 m, HTS bulk, 3.5/10/35 kV superconducting fault current limiters, a 5 MJ flywheel with superconducting magnetic bearings, and of a 0.2 MW superconducting motor. Other devices to be developed include a 1 MVA superconducting transformer, a 1 MVA superconducting generator, a 1 MJ superconducting magnetic energy storage (SMES) system, and 70 kA current leads for magnetic fusion energy systems, devices, and other settings. The program will also conduct tests and studies of large superconducting windings, components, and prototype HTS devices.

HTS Coils Achieve I_c of 41 to 45 A in Testing

"We have established technological cooperation with several Russian design and manufacturing companies during the development of the wind turbine generator," Ilyasov said. "The solutions achieved and experience obtained will also be used in the development of HTS machines for power equipment and vehicles."

For the rotor, the MAI-led team redesigned, fabricated, and tested 2G HTS field coils made with 4.9 x 0.35 mm 2G YBCO tapes produced by AMSC and SuperOx. The tests demonstrated an I_c of 41 to 45 A in self field within the ferromagnetic core at 77 K.

The researchers used a copper inner frame that improved the internal cooling conditions of the HTS winding coils and reduced the magnetic field in the area. The copper frame also contributed to the increase in I_c.

Motor Rotating Velocity Raised to 600 RPM

"We debugged the current input modes and tested the HTS-2G tapes under magnetic field," Ilyasov noted. "On the basis of the positive experimental results, we assembled and tested the generator in an open circuit regime. About 5.2 km of superconducting wire was used for the generator and 1.5 km for the motor, for an output power of 200 kW."

The field winding of the rotor was placed in a rotating cryostat, which had the effect of limiting the thermal flow to the rotor. A wave multiplier was used to increase rotating velocity from 15 RPM up to 600 RPM and reduce the weight of generator.

"With the final on-line tests of the assembled synchronous generator we will obtain experimental load performances for active and active-inductive loads alongside controlling characteristics. In the near future a full range of tests are planned, including climatic testing at -50° C, overload regime, and mean time between failures (MTBF). We are looking at the shores of the Arctic Ocean and the Crimea peninsula for the testing of the actual wind turbine." ❍

Proton Therapy Sales Drive IBA Revenues Higher

IBA reported that sales of proton therapy and other accelerators for the first nine months of FY2015 rose by 25.9%, to €149.4 million ($166.9 million) from €118.3 million ($132.1 million) over the first three quarters of 2014. The backlog for the Proton Therapy and Other Accelerators division at the end of Q3 reached €305 million ($340.7 million), 72% higher than the €177.4 million ($198.2 million) backlog at the end of Q3 FY2014.

The strong backlog reflects a record order intake of seven proton therapy orders consisting of four ProteusPLUS systems totaling nine rooms and three ProteusONE compact proton therapy systems, as well as eight other accelerator orders. Two contracts for a total of four rooms were signed during Q3. IBA has agreed to provide an additional two rooms at the Guangdong Hengju Medical Technologies Co. Ltd. as well as a ProteusPLUS system, including one gantry treatment room and a research and development room, at the Angel Roffo Institute of Onocology hospital in Buenos Aires.

After the end of the quarter IBA announced that it had signed contracts with Proton Partners International (PPI) to install three ProteusONE systems in private clinics in the UK: one in Newport, Wales; one in Newcastle, England; and a third at a location to be identified at a later stage. The total value of the equipment and long-term service agreements is about €35 to €40 million ($39.1 to $44.7 million) per center.

Total Revenues Grow by 25.1%

Total group revenues were 25.1% higher at €188.9 million ($211 million) compared to €151 million ($168.7 million) over the comparable period last year. IBA's share price rose by 1.6%, from €31.85 ($34.87) to €32.35 ($35.42), on the day the company issued its announcement.

IBA reiterated that it expects to achieve average revenue growth of greater than 10% per year from 2015 to 2018. However, owing to its strong performance in the first nine months of 2015, the company now expects top line growth of 15 to 20% for the full year FY2015.

IBA also confirmed that it expects its operating margins to stabilize at 10% in 2015 and then grow at 1% per year through 2018. Net debt is expected to stay limited over the coming years. It plans to maintain its target dividend payout ratio at 30%. ❍

ISTEC Creates Novel Gradiometric SQUID

Researchers at Japan's International Superconductivity Technology Center (ISTEC) have fabricated a small biaxial gradiometric superconducting quantum interference device (SQUID). The HTS SQUID is suitable for detecting magnetic signals from a sample surface with high spatial resolution. The work received financial support from the Japan Science and Technology Agency's (JST) Strategic Promotion of Innovative Research and Development (S-Innovation) program.

"This work was not done aiming at a particular application system," commented Seiji Adachi, Senior Research Scientist at ISTEC. "The small biaxial gradiometric SQUID would be useful for testing semiconducting circuits and solar cells. Of course, it would be convenient as the sensor head of a SQUID microscope as well.

"Many researchers are investigating nanoSQUIDs using LTS. It is possible to fabricate biaxial LTS SQUIDs with higher spacial resolutions.

"One of the most important features of our device is its working temperature of 77 K. It may be the smallest biaxial gradiometric SQUID operating at this temperature."

ISTEC SQUIDs Feature Ramp-edge Josephson Junctions

In recent years ISTEC researchers have developed SQUID systems with HTS for a variety of applications including non-destructive evaluation, mineral exploration, and immunoassay. Their devices have two distinguishing features: ramp-edge-type Josephson junctions and oxide multilayer structures.

"In HTS REBCO the CuO_2 plane mainly acts as a conduction path for superconducting carriers," Adachi said. "Weak links sandwiched by the upper and lower CuO_2 planes act as superconducting barriers. We expect ramp-edge-type Josephson junctions to function stably, even with environmental magnetic perturbations, when compared to bi-crystal and step-edge-type junctions.

"Design flexibility is significantly improved by applying a multilayer structure. This multilayer structure was indispensable for realizing our biaxial SQUID.

"This newest biaxial SQUID consists of two gradiometric SQUIDs with a baseline length of 30 μm. It contains 4 junctions and 16 crossovers on a chip and includes nine superconducting contacts between counter- and base-electrodes. Depositing a counter-electrode simultaneously prepares the junctions and the superconducting contacts."

Ion Bombardment used to Prepare Junctions and Contacts

The team developed a technique using ion bombardment for the ramp surfaces of the base-electrode in advance of counter-electrode deposition. They used this ion bombardment process for the preparation of modified oxide layers suitable to form the junctions and the contacts. They controlled the ion incident angle against the ramp surface during bombardment.

"I investigated the relationship between the angle and the interconnection characteristics between counter- and base-electrodes," Adachi said. "The angle is critically important to distinguish the preparation of Josephson junction and superconducting contacts. The composition and thickness of damaged layers at the ramp surface are affected by the incident angles.

"$La_{0.1}Er_{0.95}Ba_{1.95}Cu_3O_y$ (L_1ErBCO) and $SmBa_2Cu_3O_y$ (SmBCO) were used as counter- and base-electrodes, respectively. A $SrSnO_3$ (SSO) was used for insulation."

Detailed Studies Ongoing

The ISTEC researchers tested the fabricated chip by passing a current through feedback coils. They confirmed that the gradiometers crossing at right angles operated properly without appreciable cross-talk.

"I observed magnetic modulations in the x-direction by passing a current through the feedback coil for the x-direction, "Adachi said. "On the other hand, no modulation was confirmed when a current was passed through the coil for the y-direction.

"Our study of the biaxial SQUID continues. Detailed evaluations of the device, including evaluations of the noise characteristics and balance, have not yet been completed." ❍

Saint Jean Carbon Identifies

Graphene Magnetic Properties

Canadian carbon sciences company Saint Jean Carbon Inc. has announced that it has produced graphene that may have magnetic properties. This accomplishment marked the completion of the initial phase of a project that has as one of its objectives the development of superconducting graphene and the subsequent collaboration with industrial partners to explore potential applications for the material.

Western University and the University of Waterloo are also participating in the research. The project began about seven months ago and is partially supported by a National Sciences and Engineering Research Council of Canada (NSERC) grant.

Magnetism Observed Without Temperature or Chemical Manipulation

The work completed under the initial phase of the project focused on identifying and clarifying the magnetic properties of graphene. These properties could play a significant role in enhancing the superconductivity of the material.

St. Jean used very pure base graphite in its research extracted from its own mines, which minimized the need for costly and environmentally harsh purification. The graphene that was produced from this graphite demonstrated excellent electrical/thermal connectivity, a large high surface area, very good wettability, and had magnetic properties.

According to Saint Jean CEO Paul Ogilvie, the graphene developed by the company exhibits magnetic properties naturally, without temperature or chemical manipulation. In addition, it can be manipulated between ferromagnetic and diamagnetic phases.

The University of Waterloo is currently conducting full magnetometer temperature testing on St. Jean's graphene. The company plans to release the testing results after it has completed the filing of a number of provisional patents on its graphene technologies, production processes, and potential applications.

Company to Identify Partners to Develop Applications

The research relied on a patented nanoparticle ultrasound separation system that isolates and creates large quantities of graphene at a reasonable cost. The company has suggested that this production method is less aggressive and more cost effective than alternatives such as the Hummers' Method. The process has the potential to shorten the time needed to develop graphene applications for the marketplace.

Saint Jean is currently implementing the second phase of its research, which is likely to continue into spring 2016. This involves preparing a bench scale system capable of producing larger quantities of high purity graphene samples for potential industry partners. The company plans to identify and work with these partners to devise solution-based applications for its production process that can be developed today and be within use in a short time frame.

Key Potential Applications include Bioengineering and Nanoelectronics

St. Jean envisions developing applications for its graphene both in non-superconducting applications, in fields such as bioengineering, and superconducting applications, either as a superconductor or to enhance superconductivity in other materials. As an example of the latter, the company suggests that graphene could be combined with MgB_2 by interspersing the alternating boron and magnesium atomic layers with individual layers of graphene to improve that material's efficiency as a superconductor. As a possible superconducting material itself, graphene could potentially be used in nanoelectronics and as a substitute for silicon in the circuitry of a wide variety of electronic devices.

"One of the next steps in our go-forward plan is to quickly advance the product applications by working with a number of companies and potential strategic partners," commented Saint Jean CEO Paul Ogilvie. "Given the potential of graphene in everything from quantum computing to energy storage, Saint Jean has been encouraged by the breadth and depth of these preliminary discussions."

Saint Jean is a publicly traded carbon sciences company that owns a number of graphite mines in Quebec. The company is pursuing a vertical integration strategy that includes the commercial-scale production of value-added downstream products in the emerging graphene sector. ❍

French Team Induces SC in Boron-doped Silicon

Scientists from France's Institute of Fundamental Electronics (IEF) of the University of Paris-South; Institute Neel of the University Joseph Fourier, Grenoble; the Institute for Nanoscience and Cryogenics (CEA-INAC); the Nanotechnology Institute of Lyon; and the IEP of the Slovak Academy of Sciences have demonstrated that superconductivity can be induced in boron-doped silicon (Si:B). T_c rapidly increases above a critical boron concentration and is fully determined by the boron dose.

The team also investigated how Si:B might be structured for superconducting applications such as Josephson junctions and SQUIDs. The study has received financial support from France's National Research Agency (ANR).

Covalent superconductors, superconducting materials where the atoms are linked by covalent bonds, were first observed in 2004 through the heavy p-type doping with boron of synthetic diamonds grown by the high-pressure high-temperature (HPHT) method. Superconductivity at ambient pressure in boron-doped silicon was discovered in 2006. This was followed in 2008 with superconductivity in silicon carbide that had been heavily doped with boron or aluminium.

Si:B Offers Advantages for Nanoelectronics

Superconducting Si:B has generated interest among researchers due to its potential for use in applications. Silicon technology is arguably the most mature for nanoelectronics and can be used to elaborate built-in structures in a single silicon crystal, thereby avoiding the difficulties of assembling heterogeneous devices, for example growth in the presence of different lattice constants or different thermal expansion parameters.

The stability of Si:B structures also holds promise for developing complex architectures where the technology can be controlled in terms of reproducibility, variability, and know-how. Because of these attributes, theorists have suggested that qubits may be realized using Si:B. Superconducting circuits are very versatile, and can be used in a variety of devices from sensors to quantum computers.

In parallel, epitaxial semiconductor devices such as spin qubits in silicon offer more limited device variation but extraordinary quantum properties, such as very long spin coherence times. Single-crystal superconducting silicon devices may combine the advantages of both silicon and superconductivity.

Extreme Doping Concentration Triggers SC

However, extreme doping concentration is required to trigger superconductivity, with more than three times the boron solubility limit required in silicon to reach a superconducting state. This concentration cannot be reached using conventional micro-electronic techniques, but gas immersion laser doping can be employed to develop epitaxial superconducting Si:B thin films.

Professor Francesca Chiodi at IEF explained how the research team observed that T_c was not dependent on the boron concentration or the doped thickness but the boron dose: “We studied the T_c dependence in many series of samples, each with a fixed thickness and increasing boron concentration. We suddenly remarked after tracing all the curves against the number of laser shots that the total boron dose (the number of B atoms per cm^2) made all the curves collapse into one (doi: 10.1103/PhysRevB.88.064508).

“As of now, T_c can be varied from 0 to 0.7 K by increasing the boron dose. By optimising the doped spot homogeneity we also managed to increase the T_c from the maximum of the first studies, 0.35 K, to the actual maximum of 0.7 K. Fundamental in raising the T_c is the ability to dope more and more above the solubility limit, which we can do thanks to gas immersion laser doping.”

Metallic Phase Enhances Applications for Nanodevices

Si:B does not transition directly from a semiconducting state to a superconducting one, but first becomes metallic. This makes the fabrication of a large range of nanodevices possible in which superconductors, metals, and semiconductors can be coupled through very clean, epitaxially grown interfaces.

“We could easily realise superconductor (S)/normal metal (N)/superconductor (S) Josephson junctions from S/N laser doped bilayers,” Chiodi said. “The weak link is the metallic silicon doped wire, which of course could be replaced by a semiconducting wire. However, a metallic weak link insures a better interface transparency with the superconducting Si, which is still sensitive to a gate effect because doped Si has a much weaker carrier concentration than metals “

Silicon Devices Tested

The researchers demonstrated the possibility of structuring the strongly boron-doped Si for developing superconducting micro- and nanodevices. They achieved initial results building and measuring all-silicon S/N/S Josephson junctions, SQUIDs, and microwave resonators (doi:10.1016/j.apsusc.2013.10.101 and doi:10.1063/1.4928660).

“The SQUIDs and resonators were realised from a single layer of superconducting Si,” Chiodi said. “For the SQUID we simply etched into the Si:B layer the structure of a ring with two weak links. The SNS Josephson junctions were realised from SN bilayers, which were easily realised with the GILD technique.

“We conducted multiple tests to see if the usual clean room fabrication steps affected superconducting silicon, and found that most of the processes are unchanged from Si treatment. These include etching recipes or etching velocity, and the ability to use these techniques represents a great technological advantage.

“Our short term objective is to realise the first all-silicon Josephson Field Effect Transistor and to work on superconducting silicon coplanar waveguides in collaboration with the Cryogenic Detectors group at the Center for Nuclear and Material Sciences (CSNSM) at University Paris-South. If the research on resonators is successful, we will tackle superconducting silicon detectors for astrophysics photon detection. This research direction is very exciting but still needs to be demonstrated experimentally.” ❍

CAS Team Improves Transport J_c in $SmFeAsO_{1-x}F_x$ Tapes

Researchers from the Chinese Academy of Sciences (CAS) and Tohoku University of Japan have improved the transport J_c in $SmFeAsO_{1-x}F_x$ tapes by using the powder in tube (PIT) method. Their work may increase the attractiveness of the 1111 family of iron-based superconductors for eventual use in applications such as high field magnets. The study received funding from the Chinese 973 Program (Grant No. 2011CBA00105),

the Natural Science Foundation of China (NSFC - Grant No. 51025726, 51320105015 and 51202243), and the China-Japan Bilateral Joint Research Project of the NSFC and the Japan Society for the Promotion of Science (JSPS).

"This work is part of a program focused on practical wire fabrication research using iron-based superconductors including the 122, 1111, and 11 types," commented Researcher Qianjun Zhang of the CAS Key Lab of Applied Superconductivity. "Our research into various types of iron-based superconductors is intended to promote the practical applications of this HTS family.

"We recently made progress in the J_c enhancement [Sci. Rep. 4 (2014) 6944] and long-length fabrication [Physica C 516 (2015) 17] of PIT 122 tape conductors. In addition, our group recently achieved high-performance 11 type films by pulsed laser deposition (PLD) [Supercond. Sci. Technol. 28 (2015) 065009]."

SmFeAsO has Highest T_c of Iron-based Superconductors

Iron-based superconductors are considered to have potential for high field applications because of their very high upper critical field, large J_c, relatively small anisotropy, and strong intrinsic pinning. The 1111 pnictides, which include SmFeAsO, have attracted a great deal of interest due to having T_c's as high as 56 K.

"1111 superconductors can be used with Cu-sheath or Fe-sheath metals instead of expensive Ag-sheath for the scalable production of wire based on the PIT method," Zang explained. "In addition, the in-field J_c for 1111 is much lower than self-field J_c. The T_c of SmFeAsO is higher than any other type of iron-based superconductor, providing a broader operational space for high-field applications."

Sn Pre-sintering Improves Grain Connectivity and J_c

Although the PIT method shows promise for fabricating wires from the 1111 family, achieving a high transport J_c has been hampered by difficulties such as grain connectivity, fluorine control, and impurity control. The CAS-led team sought to solve these problems by applying a precursor powder through a Sn pre-sintering process on the $SmFeAsO_{1-x}F_x$ tapes.

"The quality of 1111 precursor is a crucial factor that determines the final performance of wires," Zhang said. "We proposed Sn pre-sintering to take advantage of the properties of Sn for improving precursor quality, which led to further J_c enhancement compared to the conventional methods of adding Sn to 1111 wires.

"Sn has previously been used as a flux for the growth of 122 pnictide single crystals. Our group has used it as a metal additive in 122 and 1111 superconducting wires to improve the grain connectivity and crystallization.

"Sn does not react with 122 or 1111 pnictides. It is located at the grain boundaries of the pnictide phase, promoting the crystallization of the superconducting phase, reducing the glassy FeAs phase, and filling the pores between grain boundaries during the heat treatment of wires."

Heat Treatments Prevent Fast Fluorine Loss

The researchers also applied a series of low-temperature (300° to 500°C) heat treatments under ambient or uniaxial pressure, which effectively avoided fast fluorine loss in the tapes and prevented the formation of reaction layers between the superconducting core and sheath metal. Using transport current measurements and magneto-optical imaging, they confirmed a highest transport J_c of 3.95 x 104 A cm^2 at 4.2 K and self-field.

Zhang cautioned that controlling for impurities remains an area for future work: "Impurities such as SmAs and SmOF, which occur due to fluorine loss, are still an unsettled problem. In addition to the high-temperature (around 1100°C), short-time annealing technique that our group had previously employed, our new low-temperature process may prove effective in controlling fluorine content [Supercond. Sci. Technol. 28 (2015) 105005]. We are continuing our efforts to enhance the in-field J_c of 1111 wires by obtaining high-purity 1111 precursor, reducing the fluorine loss, and improving the density of the 1111 phase." ❍

HKUST Uncovers Reason for High Field Resistance in MoS_2

Researchers at Hong Kong University of Science and Technology (HKUST) have provided an explanation as to why superconducting thin films of MoS_2 can withstand applied magnetic fields as strong as 37 T. The ability of the MoS_2 thin films to withstand high fields was first discovered by researchers in the Netherlands. Normally, the electron pairs that enable superconductivity are broken by strong magnetic fields.

The HKUST team found that the lattice structure of MoS_2 thin films allows for electrons to experience strong internal magnetic fields of about 100 T. This special type of internal magnetic field, instead of damaging superconductivity, protects the superconducting electron pairs from being destroyed by external magnetic fields.

Team Dubs New SC Class

Ising Superconductors

The team dubbed such superconductors Ising superconductors. They also predicted that many other superconductors with similar lattice structures as MoS_2 would fall into the same family of Ising superconductors.

The HKUST team also found that Ising superconductors can be used to create Majorana fermions, which have potential application in making quantum computers. In collaboration with experimentalists from Penn State University, the research team found that a monolayer of $NbSe_2$ is also an Ising superconductor. ❍

Superconductivity Roundup

Events & Opportunities from Around the Industry

SW Operators at the **LHC** are now colliding lead-ions for the first time since the facility was last shut down and at energies twice as high as were previously possible. Positively charged lead ions will be collided for a one month period at the CERN facility.

SW **Trillium US Inc.**, headquartered in Clackamas, OR, has announced the acquisition of the **Oxford Instruments' (OI) Austin division**, formerly known as Austin Scientific. Focused on the helium compression-based vacuum and temperature management and control sector, OI-Austin provides cryo pump, cold head, and compressor service, a range of new cryogenic pumps, cold heads, and helium compressors, as well as a full line of related spare parts and accessories. Trillium currently operates a 12,000 ft^2 facility in North

Austin servicing primarily rough vacuum pumps and blowers, while the existing 23,000 ft^2 OI-Austin facility is located in South Austin.

sw The communications company **Telstra** has invested AU$10 million ($7.2 million) in a **University of New South Wales** project to develop a practical quantum computer, matching a AU$10 million ($7.2 million) contribution from the **Commonwealth Bank**. The money comes on top of AU$26 million ($18.8 million) for the project from the **Australian government**.

Telstra CEO Andy Penn said the company had agreed in principle to invest $10 million in the project plus give in-kind support from its data scientists. The AU$10 million invested by the Commonwealth Bank builds on AU$5 million ($3.6 million) which the bank invested a year ago in the research being done at the UNSW-based Center for Quantum Computation and Communication Technology.

The UNSW project team is developing its quantum computer components in silicon, the material now most commonly used to make computer chips. A silicon-based system may be more easily scaled into commercial manufacture than some of the more exotic designs used by other research groups.

The new money from the Australian government, Telstra, and the Commonwealth bank will cover more than half of the $70 to $80 million necessary to achieve the research team's next goal of building a 10 qubit silicon-based quantum computer by 2020. It is estimated that at least 300 qubits are needed to realize the potential of quantum computers to speed up computing operations.

sw A team of researchers from **Google's** artificial intelligence labs has published results which claim to have demonstrated that the company's **D-Wave** quantum computer relies on quantum effects. Google bought a $10 to $15 million D-Wave quantum computer in 2013 for installation at the Quantum Artificial Intelligence Lab (QuAIL), a collaboration with NASA located at NASA's Ames Research Center in Mountain View, CA (see *Superconductor Week*, Vol 27, No 7).

D-Wave claims to produce the world's first quantum computing systems. The extent to which D-Wave's computing technology qualifies as quantum is controversial in the academic community. In particular, some researchers have questioned whether or not D-Wave's systems have shown quantum entanglement, an indicator that it relies on quantum effects.

One theory that has been posited is that the machine's qubits are in fact tiny electromagnets that enable it to perform certain functions at unprecedented speeds. Teams of researchers have been unable to prove whether or not the computer actually takes advantage of true quantum effects.

D-Wave relies on a process called quantum annealing in its computing systems, which is enabled by quantum tunneling. The process apparently allows D-Wave's systems to find an optimal solution from a set of combinations at speeds thousands of times faster than conventional software. However, the system is reported to have limitations when it comes to solving problems that do not involve finding an optimum solution from among a set of combinations.

The team from Google, whose results were published on the arXiv server, conducted a series of experiments in which it pitted its D-Wave quantum computer against a regular computer with a single processor and had them race through optimization problems known as annealing. The regular computer used a technique known as simulated annealing, while the quantum computer used quantum annealing.

Google claims that for problem instances involving nearly 1000 binary variables, quantum annealing significantly outperformed its classical counterpart. The quantum system performed more than 10^8 times faster than simulated annealing running on a single core.

The results have not yet been peer reviewed. Some researchers have casted doubt on aspects of the study. The choice to run an annealing process on the conventional computer meant that it was not operating as fast as it could have, and some researchers were quoted in the media stating that the problem sets chosen by Google were intended to be easier for the D-Wave computer to solve.

sw **Research and Markets** has released a report entitled: "**Low- and High-T_c Superconductor Wire - Global Markets, Technologies, Opportunities, and Competitors: 2015 to 2020 Analysis and Forecasts**." The report predicts a renaissance of superconductivity applications in the next three to seven years and claims that this will be based not on incremental progress in the existing technologies but rather on breakthroughs in rapidly growing industries such as clean energy and electric power equipment.

sw **Sinovel Wind Group Co. Ltd.** is involved in a new U.S. lawsuit involving its business dealings with **American Superconductor**. **The U.S. Department of Justice** has reportedly launched criminal proceedings against the company and three individuals regarding charges of alleged fraud, patent infringement, illegal obtaining of commercial secrets, and conspiracy.

sw The **Federal Energy Regulatory Commission** (FERC) has approved transmission service agreements and large generator interconnection agreements between **Tres Amigas** and three wind power projects owned by **Pattern Energy Group**. The transmission service agreements were accepted subject to condition, since the transactions involve an affiliate, Western Interconnect, which was directed to make a compliance filing to complete the transfer of the agreements.

Western Interconnect was formed by Pattern and Tres Amigas, with Pattern owning a majority interest and Tres Amigas a minority interest, for the sole purpose of developing, building, and operating a 35-mile, 345-kV transmission line to connect Pattern's wind power projects to the Public Service Co. of New Mexico system at the Blackwater switching station in Clovis, NM. The line will have a capacity of about 1,100 MW, and the wind projects have a total capacity of 497 MW. Construction of the transmission line is expected to start in the next three months.

Tres Amigas has been working for several years to connect the three U.S. Power grids, or interconnections, with superconducting DC cables at a so-called Superstation in northwest New Mexico. However, the project has seen numerous delays to the beginning of construction and has had difficulty arranging an agreement with the Electric Reliability Council of Texas, which manages the Texas power grid.

The original plan was for the wind projects to become transmission customers of the Superstation, but because the wind projects have been developed faster than the Tres Amigas project they required interconnection and transmission service before Tres Amigas could finance and build the Superstation. The transmission agreements would serve as anchor contracts for the 1,100 MW line, with Tres Amigas vowing to offer the same rates, terms, and conditions to others in an open season, FERC said, noting that the original transmission rate was for $27,500/MW-year for each of the projects.

Pattern formed Western Interconnect with Tres Amigas "because Pattern was concerned that Tres Amigas would have difficulty in financing construction of the transmission line since it has no other sources of revenue, the FERC said. The line would be operated by Western Interconnect until such time as Tres Amigas obtains financing and begins construction of the Superstation, with Tres Amigas then purchasing Pattern's majority interest in the transmission line.

Superconductor Week
Commercialization · Markets · Products
Business Developments · R&D · Cryogenics
~Insert~
December 31, 2015 Vol. 29, No. 12

Superconductivity Stock Index

Company Name	Symbol	Prices ending 31-Dec-2014	Prices ending 30-Nov-2015	Percentage change
American Superconductor	AMSC	7.40	4.71	-36%
Oxford Instruments	OXIG.L	19.51*	9.86*	-49%
Superconductor Technologies	SCON	2.77	0.22	-92%
Bruker Corporation	BRKR	19.62	22.64	15%
Furukawa Electric	5801	1.68**	2.17**	29%
Ion Beam Application	IBAB.BR	17.35***	31.91***	84%
Superconductor Index (12/31/14 = 100)		100.00	111.29	11%
Standard and Poor's 500		2058.90	2,080.41	1%

The Superconductivity Stock Index is a market value index as is the S&P500. It is generated by Peregrine Communications. The year-to-date percentage change is based upon the change in market value of the companies in the index. Market value is determined by the share price times the number of shares outstanding at the end of the measured period.

* Figures are derived from closing rates on the London Stock Exchange, converted from UK Pounds to U.S. Dollars
** Figures are derived from closing rates on the Tokyo Stock Exchange, converted from Japanese Yen to U.S. Dollars
*** Figures are derived from closing rates on the Brussels Stock Exchange, converted from Euros to U.S. Dollars

U.S. Superconductivity Patents

MR-based Viscometers and Methods
Massachusetts Institute of Technology; The General Hospital Corporation
Aug. 4, 2015
U.S. Patent No. 9097644
This invention relates generally to MR-based methods and kits for measuring the viscosity of liquid samples.

Surface NMR Coil
Exxonmobil Upstream Research Company
Aug. 11, 2015
U.S. Patent No. 9103889
There is disclosed a flat NMR coil system especially adapted for evaluating thin samples of material(s), or samples in which a thin surface region of the sample is to be examined. The apparatus and method work well in a static magnetic field oriented generally perpendicular to the planes of the flat sample and coil. In one preferred mode, the coil is located approximately parallel to (and generally proximate to or in flush contact with) the surface of the subject sample, while the coil typically also is oriented so that the flux of the strong static field for performing the NMR is approximately normal to the planes of the coil and the sample surface. The coil has a wire path routed to define at least one continuous "figure eight" double loop arrangement, to improve operational performance of the complete coil.

SC Flat Tape Cable Magnet
Aug. 11, 2015
U.S. Patent No. 9105396
A method for winding a coil magnet with the stacked tape cables, and a coil so wound. The winding process is controlled and various shape coils can be wound by twisting about the longitudinal axis of the cable and bending following the easy bend direction during winding, so that sharp local bending can be obtained by adjusting the twist pitch. Stack-tape cable is twisted while being wound, instead of being twisted in a straight configuration and then wound. In certain embodiments, the straight length should be half of the cable twist-pitch or a multiple of it.

Oxide SC Thin Film and SFCL
Furukawa Electric Co. Ltd.; National Institute of Advanced Industrial Science and Technology

Aug. 11, 2015
U.S. Patent No. 9,105,794
An oxide SC thin film includes a substrate having a single crystal structure, the main face of the substrate and a crystal face of the single crystal structure having an angle therebetween; an intermediate layer formed on the main face of the substrate and having an axis oriented in a direction perpendicular to the crystal face; and a SC layer formed on the intermediate layer and containing, as a main component, an oxide SC having a c-axis oriented in a direction perpendicular to the surface of the intermediate layer. A SFCL and a method of manufacturing an oxide SC thin film are also provided.

Composite SC
Inter-University Research Institute Corporation National Institutes of Natural Sciences; Furukawa-Sky Aluminum Corporation; Furukawa Electric Co., Ltd.
Aug. 11, 2015
U.S. Patent No. 9105795
Disclosed is a composite SC comprising a SC and a metal member. The metal member is composed of one or more members to be joined together in such manner that the one or more members cover the SC, and at least one member is made of aluminum or an aluminum alloy.

Drift Tube Linear Accelerator
Mitsubishi Electric Corporation
Aug. 11, 2015
U.S. Patent No. 9107281
According to the drift tube linear accelerator of the invention, its acceleration cavity is configured with a center plate and a pair of half cylindrical tubes, wherein the center plate includes a ridge, stems connecting the ridge and drift tube electrodes, and the drift tube electrodes, and wherein the acceleration cavity is configured, as seen in cross section perpendicular to a beam-acceleration center axis, whose inner diameter in X-direction that is perpendicular to a central axis in planar direction in which the stem of the center plate extends and that is passing through the beam-acceleration center axis, is longer than whose inner diameter in Y-direction parallel to the central axis in planar direction.

Magnetic Conductive Device
Aug. 18, 2015
U.S. Patent No. 9108038
A computerized electrical powered apparatus where one part is different types of housings with or without a cover. The apparatus produces magnetic field, for inducing water, in the housing (if a shower: inducing water, and water-vapor (mist) via a plumbing assembly). The housing uses: CO_2 liquid cooling to cool electrical circuit boards, electromagnet(s), nanotube(s), nanowire(s), that control: water, elements, nutrients, drugs, found in blood, living tissues, vegetation tissue(s) of any organism(s). In another aspect; an extractor capturing molecule(s) in steam derived from compounds, drugs, that converge with a SC wire transporting ionic compounds, molecular ions; rise out from hot water, H_2O-steam, and dry gases feed extractor, into a cooled catalyst pipe linking to a housing. The pipe with the wire inside, attach inside the housing, where the mixture disperses. A digital numerical image is captured on a computer monitor by rotating hydrogen molecules of water in the housing.

No-insulation Multi-width Winding for HTS Magnets
Massachusetts Institute of Technology
Aug. 25, 2015
U.S. Patent No. 9117578
An HTS magnet having a stack of a plurality of double-pancake (DP) coils is disclosed, with each DP coil having a first SC coil and a second SC coil. The plurality of DP coils have varying widths, with DP coils with the widest widths at the top and bottom of the stack, and DP coils with the narrowest coils located substantially at a midpoint of the stack. The DP coils omit turn-to-turn insulation, or have minimal turn-to-turn insulation.

Improving Reliability of a FCL System
Varian Semiconductor Equipment Associates, Inc.
Sept. 1, 2015
U.S. Patent No. 9121879
Techniques for improving reliability of a SFCL are provided. In one particular exemplary embodiment, the technique may be realized as a method of improving a reliability of a SFCL, the SFCL system comprising a SC provided in a container. The method may comprise

providing one or more sensors capable of detecting a fault current proximate to the SC; determining a change in the condition of the SC as a result of the fault current; and estimating the lifetime of the SC based on the change in the condition of the SC.

Connection Structure for SC Cables

Furukawa Electric Co. Ltd.

Sept. 1, 2015

U.S. Patent No. 9123455

A connection structure for SC cables includes: SC cables that are connected to each other and include cable cores containing formers and SC conductor layers, and each cable core is housed in a thermal insulation tube with a cooling medium, wherein the cable cores include electric insulating layers obtained by winding insulating sheets around the SC conductor layers, the electric insulating layers on both sides of a conductor connecting part, in which the formers and the SC conductor layers are connected to each other, include taper shape portions each having a diameter reducing towards the conductor connecting part, each taper shape portion is formed so as to have an inclination angle changing in a stepwise fashion by a plurality of tapered portions among which a tapered portion nearer the conductor connecting part has smaller inclination angle, and a reinforcing insulating layer is provided between the taper shape portions.

Arrangement with at least One SC Cable

Nexans

Sept. 1, 2015

U.S. Patent No. 9123459

An arrangement is provided at least one SC cable and a first cryostat. A second cryostat is provided, formed coaxially with and at a distance from the first cryostat. Arranged in the intermediate space between the first cryostat and the second cryostat is a high voltage resistant insulation which completely surrounds the outer pipe of the first cryostat, and which rests on the latter, where liquefied gas conducted during the operation of the arrangement flows through the intermediate space around the insulation and impregnates the insulation.

Increasing the Energy Scale of a Quantum Processor

D-Wave Systems Inc.

Sept. 8, 2015

U.S. Patent No. 9129224

Increasing the energy scale of a quantum processor improves its performance. Energy scale of a quantum processor may be increased by increasing the coupling strength of communicatively coupled SC devices comprised in the quantum processor. Configuring the physical dimensions of communicatively coupled SC devices such that an intentional direct coupling is induced between a pair of SC devices communicatively coupled by a coupling device may controllably add an additional mutual inductance to the mutual inductance of the pair of SC devices. Furthermore, reducing the beta parameter of a coupling device may improve the tunability of the coupling device. The combined effects of improved tunability of the coupling devices and the increased coupling strength between SC devices communicatively coupled by respective coupling devices comprised in the quantum processor may thus improve the performance of the quantum processor.

Metallic Interconnects for SC Integrated Circuits

Hypres Inc.

Sept. 8, 2015

U.S. Patent No. 9130116

SC integrated circuits require several wiring layers to distribute bias and signals across the circuit, which must cross each other both with and without contacts. All wiring lines and contacts must be fully SC, and in the prior art each wiring layer comprises a single metallic thin film. An alternative wiring layer is disclosed that comprises sequential layers of two or more different metals. Such a multi-metallic wiring layer may offer improved resistance to impurity diffusion, better surface passivation, and/or reduction of stress, beyond that which is attainable with a single-metallic wiring layer.