Nanostructured thin films synthesis: A new frontier at the Magnet Lab
Page 5

High B/T Facility opens fast turnaround 10 mK-10 T annex.
Page 17
TABLE OF CONTENTS

3  Director’s Desk: Exciting changes to our user hub, report on the NSF site visit

5  Nanostrutured thin films synthesis: a new frontier at the Magnet Lab

7  Fermi surface of a-Uranium at ambient pressure

10 Series Connected Hybrid moves forward with development of 20 kA joints

13 SCH support: plans for modernized cryogenic system debut

17 High B/T opens 10 mK -10 T annex

18 Diverse missions, common goal: the members of the Magnet Lab Center for Integrating Research and Learning team

20 In remembrance: Robert Powell Guertin

23 People

25 Science Starts Here: Yury O. Tsybin

Trying to reduce your carbon footprint? Sign up for an online subscription at http://www/mediacenter/publications/subscribe.aspx

On the cover: User support scientist Phil Kuhns works in Cell 7. Photo by Larry Gordon
New and improved magnet time proposal system to debut in January 2010

By Greg Boebinger

As you know, the MagLab's User Program consists of seven user programs each focused on a unique facility:

- DC Magnets
- Pulsed Magnets
- High B/T ultra-low temperatures
- Ion Cyclotron Resonance
- Electron Magnetic Resonance
- Nuclear Magnetic Resonance
- Advanced Magnetic Resonance Imaging and Spectroscopy.

As each program was developed in the 1990s the MagLab developed historically to have a different procedures for applying for magnet time at each of its seven facilities. No two were the same, as they were long-ago tailored to the specific facility and scientific modus operandi of each user community.

However, starting in January we will roll out a single MagLab-wide procedure for applying for magnet time at any of our seven user facilities. Any user will be able to go to the MagLab User Hub (www.magnet.fsu.edu, click on “Users”) to start the process.

Hasn't the less formal present-day system served us well to date? Yes. So why the change, and why now? Several reasons:

- An increasing number of users are accessing multiple MagLab user facilities. It doesn't make sense for these users to be submitting separate proposals on the same science, just because the research program involves experiments at several MagLab facilities.
- Each user facility is hosting an increasingly multi- and interdisciplinary community of users. We want to make sure that it is the science, not the procedures, that determine the ongoing growth of multi- and interdisciplinary research.
- Efficiency and beauty (which is the same as truth, per Keats) results from simplicity. A common database of user proposals will allow the lab to collect useful, consistent data about our User Program that streamlines our reporting of statistics and, of equal importance, gives MagLab management and advisory committees an accurate snapshot of our “core business,” the MagLab User Program writ large and the seven specific user programs therein.
- And finally, we need to keep pace with the growth of our User Program: One in four users last year was new to the MagLab, and we're not looking to get any smaller. A more unified and transparent processing of user proposals is in everyone's best interest.

Fear not! We will still be able to respond flexibly and rapidly to new users and new scientific opportunities that arise. And the new system will allow the user programs to be distinct in the ways they still need to be. For example, the DC program works with magnet power as the primary limiting factor, so a structured scheduling plan is necessary. However, the high B/T program can’t predict how long any given experiment will last, so they prioritize a user queue, rather than schedule specific time slots. We recognize that each user program needs the freedom to operate differently within this new proposal process.
In January 2010, we’ll have failed if the new system appears confusing. If you have any questions, suggestions or problems, we want you to let us know. We’ll make sure your proposal gets into the system and we’ll make sure the process gets tweaked to perfection... or dang close to perfection.

“This is a great plan that addresses an existing concern” is a primary takeaway message from the NSF Site Visit Committee from our successful review on October 5-7.

The committee report found many other things to celebrate as well:

- the magnet technologies, including the emerging designs for high-temperature superconducting magnets;
- the scientific productivity of the lab, including the growth in the Chem/Bio programs; and
- the vibrancy of the MagLab user community, including the effectiveness of the User Collaboration Grants Program in serving the user programs.

And they recommended full funding and a renewal of our NSF grant … decisions that are made at higher levels, but not without this strong level of support in the NSF Site Visit Report. We thank the committee for its dedication (and wisdom!) in reviewing the MagLab’s support of our users and their science.

Rock n’ roll,

*Gregory S. Boebinger*

GREGORY S. BOEBINGER
As part of the Advanced Materials Cluster of the Pathways of Excellence program at The Florida State University, an ultra high vacuum molecular beam epitaxy facility is being developed at the Magnet Lab to carry out exploratory research in nanostructured thin films.

Molecular beam epitaxy (MBE) is known for its ability to grow high-quality crystalline films of insulators, metals and semiconductors. This growth technique has been developed and advanced over the years to produce two-dimensional electron gas structures in compound semiconductors with values for mobility that exceed $1 \times 10^7 \text{ cm}^2/\text{V}\cdot\text{s}$ and high-temperature superconductors in thin film form with properties that rival bulk crystals. But this is not the end of the road. The versatility of MBE is such that with precise control over the elemental constituents and innovative schemes, artificial “single crystals” — crystals where the crystal structure is continuous across atomically sharp interfaces between different classes of materials having contrasting ground states — could be constructed. Proximity effects, reduced dimensionality and symmetry breaking compete at such interfaces to bring out quantum phenomena and unforeseen functionality. The intriguing possibility of creating nanostructured designer materials with tailored properties, materials and structures that do not exist in nature and cannot be created in bulk form, is the current state-of-the-art in thin films research.

Figure 1. The arrangement between atoms of a film of strontium titanate and the single crystals of silicon on which it was made is shown on the left. On the right this schematic has been written on SrTiO$_3$/Si by piezo force microscopy utilizing the ability of the ferroelectric film to store data in the form of a reorientable electric polarization.

My recent work$^1$ demonstrating the integration of a ferroelectric oxide (SrTiO$_3$) directly on silicon addresses what scientists had envisioned for over half a century: the use of ferroelectrics in semiconductor devices. Most semiconductor devices are built on a platform of silicon coated with a thin layer of silicon dioxide. In fact, it is difficult to avoid the native silicon dioxide layer because silicon readily oxidizes and can also steal oxygen from any metal oxide layers deposited on bare silicon.

The work I carried out at Penn State University with Darrell Schlom (now at Cornell) demonstrated that by careful control over the growth, ultra thin films of SrTiO$_3$, grown directly on silicon with no interfacial silicon dioxide such that the SrTiO$_3$ layer is commensurately strained to the silicon lattice could be ferroelectric. Jeremy Levy (Pittsburgh), a user of the Magnet Lab, was also part of this research effort and carried out piezo force microscopy measurements on these samples, which together with high-resolution temperature dependent x-ray diffraction measurements demonstrated ferroelectric functionality well above room temperature$^1$. This is a first time achievement for a material grown directly on silicon with no interfacial native oxide layer.

A ferroelectric/silicon hybrid device has the potential to lead to new memory and transistor devices$^2$ where the gate dielectric has a built in memory element — the two-state electronic polarization of the ferroelectric. Such integration of functional oxides (ferroelectric, ferromagnetic etc.) with semiconductors is one of the key research areas that we will actively pursue within the nanostructured thin films group at the Magnet Lab.
Another research area that is envisaged involves exploiting the many collective ground states that occur in isostructural complex oxide phases. My previous work on “digital synthesis” — a technique pioneered while working with Jim Eckstein (Illinois) where precisely integer molecular layers of different material phases are sequentially grown to create artificial “single crystals” — has led to interesting physics and new material properties that result from the interplay between structural, electronic and magnetic discontinuities at the interfaces. In three-component dielectric superlattices where the molecular stacking sequence was designed to break inversion symmetry, a high-temperature polarized material was obtained with the electronic polarization direction controlled by the direction of the stacking asymmetry. More recently, with innovative pyrocurrent measurements, I have studied the low-temperature electronic polarization states of these same materials (artificial dielectric crystals with broken inversion symmetry) and observed unusual properties unlike that of regular ferroelectrics or that observed in natural systems. Similarly, in colossal magnetoresistive manganites I have been able to control the ground state by varying the monolayer sequence in digital superlattices, finding through collaborative research both ferromagnetic, conducting ground states and insulating states with modulated ferromagnetism.

Studying such precisely nanostructured materials where proximity effects at hetero interfaces could lead to new or modified aggregate properties is interesting from both a fundamental and applied viewpoint. We will also probe fundamental materials properties and how these properties are affected by electric and magnetic fields through nanofabricated devices such as tunnel junctions and field-effect devices as well as spectroscopic techniques involving MBE grown hetero interfaces.

Finally, in our nanostructured thin films group at the Magnet Lab, we will also investigate exotic properties that occur at interfaces between superconductors, ferromagnets, ferroelectrics and band and Mott-Hubbard insulators. We are presently involved in collaborative work studying the interface between two insulating oxides (LaAlO$_3$ and SrTiO$_3$) where the specific atomic arrangement at the interface leads to a conducting 2-D electron gas. This electron gas is superconducting below 200 mK. Our work probes the origin of the 2-D electron gas and its dependence on the stoichiometry of the two insulating oxides. The use of molecular beam epitaxy, a gentle growth technique, gives us much better control over stoichiometry and helps to eliminate extrinsic effects that lead to electronic conduction in these materials, such as defects that result from the energetic nature of the typically employed growth technique — pulsed laser deposition. We will study electronic transport and magnetic properties of such exotic systems, utilizing the high magnetic field/low temperature environments available at the Magnet Lab to fully understand the quantum mechanical properties of the ground states.

REFERENCES
4. M. P. Warusawithana, J. N. Eckstein et al., to be published.
11. In collaboration with the groups of Jochen Mannhart, Darrell Schlom, Jim Eckstein and Stephen Hellberg.
INTRODUCTION

Uranium, first isolated in the 1920s, has remained a challenge for condensed matter physicists since the first scientific work on it began almost 90 years ago. The orthorhombic alpha phase of uranium (α-U) provides a unique setting to understand the role of f-electrons in the complex behavior of the actinides. The alpha phase of uranium is the only element to go through a charge density wave (CDW) transition, which does not have an accompanying spin density wave (SDW) in the material. The CDWs in α-U have historically made the observation of quantum oscillations quite difficult due to the concomitant stress and defects that were predicted to damage the crystal. Because the observation of dHvA oscillations requires very clean crystals with long electron mean-free-paths, it was thought to be impossible without suppressing the CDW state via pressure. The only Fermi surface studies previously done on α-U by Shirber and Arko were at a pressure of 0.8 GPa. With the use of the high magnetic fields, low temperatures and highly sensitive torque magnetometry available here at the Magnet Lab, we were able to detect the dHvA oscillations in α-U at ambient pressure for the first time.

EXPERIMENTAL

Our measurements were carried out in a variety of systems at the DC and Pulsed Field facilities of the Magnet Lab, including an Oxford top-loading dilution refrigerator located in a 35 T resistive magnet, a Janis variable temperature insert (VTI) housed in a 31 T resistive magnet, and a He3 cryostat in a 65 T pulsed magnet. Seiko piezo cantilevers were used to observe the quantum oscillations in all the magnet systems.
The $\alpha$-U crystals were from a 1997 electrometallurgical growth using electrotransport through a LiCl-KCl eutectic flux containing 3% UCl$_3$ by weight. The crystals were later annealed to enhance the crystal qualities for dHvA studies.

**RESULTS AND DISCUSSIONS**

As seen in the inset to Figure 1, the RRR is clearly enhanced from a typical unannealed value of 1-5 to a value of 570 indicating the low scattering rate in these crystals. Figure 2 shows a representative torque signal from a magnetic field sweep with the background subtracted for a misalignment of 65 degrees from the [100] axis towards the [001] axis at 1.4 K. Oscillations are clearly visible (top panel) and a fast Fourier transform (FFT) analysis reveals multiple frequencies. The large amplitude of the quantum oscillations displayed further demonstrates the low scattering rate of the crystals used in this study. Figure 3 shows the angular dependence of the frequencies at various orientations. The peak positions map the extremal area of the Fermi surface at ambient pressure. The observed Fermi surface has many more frequencies than those seen at high pressure by Schirber and Arko, especially at lower frequencies (e.g. $F < 500$ T). The origin could be small pockets due to incomplete Fermi surface nesting or the large magnetic fields available (i.e. 31 T) for our measurements, which allowed 21 tesla of additional information beyond what was available to Schirber for determining the frequencies. A frequency common to both experiments is the surface described by the $F_1$ peak. This part of the Fermi surface is identical within the experimental uncertainty to the $\beta$ orbit found by Schirber and Arko, demonstrating that at least this portion of the Fermi surface is insensitive to applied pressure up to 0.8 GPa or the presence of the CDWs.

**CONCLUSIONS**

We observed a rich set of orbits for $a_\beta$-U in the ambient pressure $a_\beta$ charge density wave phase. These results show that the distortions of the lattice due to CDWs do not prevent the observation of quantum oscillations. This may be because in general materials that display CDWs are themselves very sensitive to strain, which in the present case may have been reduced by the process of annealing the $\alpha$-U crystals. This process, coupled with the increased sensitivity of the cantilever measurements, enabled the observation of dHvA oscillations in $\alpha$-U at ambient pressure for the first time. These observations will enable accurate modeling of the behavior of the $f$-electrons in uranium and can be used as a check on band structure calculations. This discovery will allow the evolution of the Fermi surface to be mapped as the CDWs are suppressed with pressure.
Figure 3.
FFT results from background subtracted torque signal taken at $T \approx 1.4$ K and at various angles. Figure 3a is a contour plot with solid black dots at selected frequency peaks. Colors on the contour plot represent intensity of the FFT at fixed angle with yellow being most intense. The red dashed line represents a $1390/\cos(\theta)$ fit to the $F_1$ orbit, in close agreement with the work of Schirber. Figure 3b is a waterfall plot of the FFT for a series of angles. Offset is proportional to angular difference. Field sweeps at fixed angle were taken with the crystal rotated from [100] to [001] and the rotational axis parallel to [010].

ACKNOWLEDGEMENTS

Support for this work was provided by the DOE/NNSA under DE-FG52-06NA26193. This work was performed at the National High Magnetic Field Laboratory, which is supported by NSF Cooperative Agreement No. DMR-0654118 and by the state of Florida. P.S. is supported by the DOE under DE-FG02-98ER45707.

REFERENCES

INTRODUCTION

The Magnet Lab Series Connected Hybrid (SCH) magnet will provide an energy-efficient 36 tesla to the DC user facility by employing a 20 kA superconducting outsert coil in series with a resistive insert. The electrical joints in the superconducting outsert require low DC resistance to minimize the refrigeration requirement at the operational 4.5 K temperatures, and low AC losses to ensure good stability against quenching during the fast ramps required by DC users. A reliable, robust solderless joint technology has been developed at the Magnet Lab to address these essential requirements.

The outsert consists of three concentric layer-wound sub-coils using three different grades of Nb₃Sn Cable-in-Conduit Conductors (CICC): High Field (HF), Middle Field (MF) and Low Field (LF). There are four internal splice joints in the outsert, which are Nb₃Sn to Nb₃Sn joints with the same design configuration. There are also two terminal joints between the Nb₃Sn outsert and the two NbTi buslines. These connect the outsert terminals to the two current leads. The two terminal joints are Nb₃Sn to NbTi joint with identical configurations. All of the joints will be praying-hands configuration with an operation current of 20 kA. This article discusses the CICC joint development activities including design, fabrication and testing activities.

JOINT DESIGN AND FABRICATION

The design of the joints for the SCH should balance the joint DC resistance and AC loss requirements while maintaining mechanical integrity. The solderless joint style has been chosen for the SCH based on the merits of low AC losses and no required handling for the brittle Nb₃Sn cable after the reaction heat treatment. The main design criteria are: the DC resistance of the joint should be lower than 2 nΩ according to the cryogenic cooling requirements; AC loss of the joint should not be the weak link on the cryogenic stability margin; no degradation is allowed during the thermal cycling and fatigue test; and leak tight in the vacuum.

The joint is enclosed entirely in a stainless steel joint box. This provides a long-term, worry-free vacuum tightness and avoids the bond between thermally mismatched materials such as copper and stainless steel, which may lead to joint deformation during cool down and the heat treatment. The superconducting cables are compressed in the joint assembly against the oxygen-free high conductivity (OFHC) copper plate at the middle. The final void fraction is designed to be 20%. The effective length of contact between strands and copper block is 300 mm, which is longer than the maximum twist pitch of the cable. The strands and the copper plate are sintered together during the first stage of the heat treatment, which provides a good current transfer without bearing a large penalty in AC losses. This eliminates the need for solder filling and other post-heat treatment processing, which reduces the risk of damage to the superconductor in the brittle state.

A full-size splice joint was designed and manufactured based on the Florida Solderless Joint Technology. In the fabrication of the joint, the conduit jacket and stainless steel foil are removed. Then the chrome plate on the surface of the strands is removed by using 37% hydrochloric acid, after which all the cables are cleaned with isopropyl alcohol. The cable area is compressed to 20% void. The stainless steel joint box is tungsten inert gas (TIG) welded to seal the joint box. Then the joint was heat treated at 640 C for 50 hours. Figure 1 shows the parts of HF-MF splice joint. Figure 2 shows the cross section of HF-MF joint.
Figure 3 shows the cross section of the terminal joint between the LF cable and busline cable. The busline will be made from round stainless steel conduit, with 40% void. The joints at the two ends will use OFHC tube as the conduit. The OFHC tube is brazed with the stainless steel and swaged to 20% void in the joint part. To reduce the pressure drop across the joint, a central perforated tube with inner diameter of 2 mm is inserted in the center of the cable. This OFHC tube is then clamped and soldered on the copper block to make the joint. The Nb$_3$Sn part of the terminal joint has the same configuration with the splice joint.

**JOINT TEST**

The full-size splice joint: High field–Middle field joint was tested after fabrication to a) fully characterize both the DC and AC performance in operational field environments and b) thermally and mechanically load cycle the joint to confirm the long-term reliability.

The HF-MF joint was tested in the 20 T Wide Bore Resistive Magnet facility (WBRM) at the Magnet Lab. The result of DC resistance of HF-MF joint is shown in Figure 4. The joint resistance shows a linear dependence with the magnetic field. The DC resistance is less than 0.6 nΩ up to 5 T. No transport current dependence is observed within the range tested. The fatigue test and the thermal cycle test were performed on the FSJ-B after the first DC resistance test. The background field is cycled between 0.5 to 4 T for 1,000 repetitions, while the transport current in the joint sample is held constantly at 20 kA. The thermal cycle was done by cooling down the experiment to 4.2 K using liquid helium and then warming up to room temperature. The test results are shown in Figure 5. No degradation has been observed in the test. Several manual synchronized ramps for both the background field and the transport current at very high ramp rate (600 A/s for the magnet, 1000 A/s for the joint) have been performed on the joint. No quenches or abnormal voltage increases have been observed.
Two different field pulse shapes have been applied in the AC test: the triangle pulse and the trapezoid pulse. In general there are four types of loss in a SC cable joint: (a) hysteresis loss of the SC wires inside the cable; (b) coupling loss of individual cable sections inside joint box; (c) eddy current loss of metal parts inside joint box; (d) inter-cable current loss, due to induced current by the pickup loop of the whole joint. The hysteresis loss is dominated at low ramp rate. The inter cable loss is dominated at high ramp rate. Figure 5 shows the total loss power as a function of ramp rate. The AC loss at the normal ramp rate of the SCH is quite small, less than 0.2 W, which is much less than the DC dissipation of the joint.

![Figure 5. Cycling test results of HF-MF joint](image1)

![Figure 6. AC loss power of HF-MF joint](image2)

The test result confirmed that the Florida Solderless Joint technology has a low DC resistance and very low AC loss. The LF-Busline joint is in the fabrication process and will be tested in the near future.

**ACKNOWLEDGEMENTS**

This work is supported by the NSF Division of Materials Research through grant DMR-0603042 and Helmholtz Center Berlin.

**REFERENCES**

INTRODUCTION

A new cryogenic system with a refrigeration capacity of 750 W at 4.5K will be built at the Magnet Lab. The cryogenic system will supply the helium refrigeration requirements of the Series Connected Hybrid (SCH) magnet and the 45 T hybrid magnet, replacing the piston expander refrigerator that has been in place for more than 15 years. The new cryogenic system will also produce liquid helium (LHe) for other magnet systems and users.

The SCH magnet is under development by the Magnet Science & Technology group at the Magnet Lab and will be a vertical bore, 36 T magnet that will be installed at the Tallahassee lab. The SCH magnet combines a set of resistive Florida-Bitter coils with a superconducting outsert constructed of Nb₃Sn cable-in-conduit conductor (CICC). The resistive insert and superconducting outsert are electrically connected in series and energized by one power supply. The outsert has a 600 mm bore and produces a peak field of 13.8 T. The SCH magnet is designed for a number of operating scenarios including multiple ramp cycles at a range of ramp rates. The stored energy is 47 MJ at the rated current of 20 kA. The average heat load of the SCH system is about 210 W at 4.5 K.

The 45 T hybrid magnet system combines superconducting and resistive magnet technologies to produce 45 T steady field in a 32 mm room-temperature bore (although at a lower homogeneity than the SCH). It has been operating successfully as a user facility for the past 10 years. The superconducting outsert is a 710 mm bore magnet that can store up to 100 MJ of energy, at over 14 T field on the axis. The present refrigerators for the 45 T hybrid system are more than 15 years old, are becoming unreliable, and require a lot of maintenance. The new refrigerator will replace the current system after the construction of the new cryogenic system is complete. The equivalent heat load for the 45 T hybrid is about 350 W at 4.5 K.

THE CRYOGENIC SYSTEM

The general considerations for the cryogenic system design are:

- The helium refrigerator will support the cooling of the SCH magnet and 45 T hybrid magnet.
- The expected excess capacity of the refrigerator will produce LHe for NMR magnets in the laboratory and other LHe users.
- The refrigerator will be able to cool the Oxford split magnet in cell 16 or potentially provide cooling for other superconducting magnets that the lab may build.
- The outsert of the SCH is forced flow cooled at 4.5 K with supercritical helium (@ > 3 bar).
- The outsert of the 45 T hybrid is cooled in a 1.8 K super-fluid helium bath.
- High temperature superconductor current leads are used in the SCH system and the associated heat exchanger is cooled by liquid nitrogen.
- The SCH and the 45 T can be either operated separately or together. They can also be cooled down (or warmed up) simultaneously or separately.
- The 80 K thermal shields for the SCH and 45 T hybrid are cooled with liquid nitrogen.
- The “20 K shield” of the 45 T magnet will be cooled between 5 K and 10 K by the new cryogenic system.
- A Central Distribution Box (CDB) will be used to distribute helium to all of the magnets.
- The cryogenic system will be designed to be safe in all expected scenarios.
- The cryogenic system will operate automatically.
Figure 1 shows the main components of the cryogenic system, which are:

1. Main compressor system of the refrigerator, with its oil removal system and gas management panel
2. Cold Box (CB) of the refrigerator, with two turbines, dual 80 K absorbers and a minimum cooling capacity of 750 W / 4.5 K
3. Three 113 m³ (18 bar) pure helium gas storage tanks and one 113 m³ (18 bar) impure helium gas storage tank
4. One CDB distributing refrigeration power and LHe to the different superconducting magnets and the LHe dewar
5. Cryogenic transfer lines between the different components
6. An 80 K coldbox and a screw compressor for cooling each magnet separately to 80 K
7. An LN₂ Dewar of 10 m³
8. An external purifier system with a capacity of 18 g/s flow rate
9. Recovery Compressors, used to pressurize helium gas in the gas bags into the impure storage tank.

Of the above equipment, the 750 W refrigerator system (including main compressor, coldbox, oil removal system and gas management panel), the SCH magnet, the CDB, the transfer lines, the helium purifiers and the 80 K coldbox are new equipment to be built and installed at the Magnet Lab.

All of the helium cryogenic valves for the cooling of the superconducting coils are integrated into the CDB. The LHe buffer in the CDB serves to store LHe and to work as a sub-cooler for the supercritical helium. The operating pressure of the LHe buffer is designed to be not more than 1.25 bar. The LHe in the buffer can also be transferred into a portable dewar.

The 45 T magnet and the SCH will be capable of being cooled down simultaneously and separately. The 80 K cold box will cool down one of the magnets while the other is at 4.5 K using liquid nitrogen for the pre-cooling.
COOLING OF THE SCH SUPERCONDUCTING MAGNET

The SCH superconducting outsert coil has 18 layers and they are forced flow cooled in parallel by supercritical helium at a temperature of 4.5 K and pressure greater than 3 bar (absolute), a significantly different scheme compared with the bath cooling used on the 45 T magnet. The scheme for the cooling of the SCH is shown in Figure 2.

The superconducting coil is cooled with helium, which comes from the Joule-Thomson stream of the refrigerator. The flow rate through the superconducting coil is controlled by the cryogenic valves in the CDB. The superconducting magnet has a 7-ton cold-mass and is in a vacuum environment, not in a helium bath. The helium mass flow rate for cooling the SCH is more than 10 g/s at 4.5 K.

COOLING OF THE 45 T HYBRID SUPERCONDUCTING MAGNET

The cold mass of the existing 45 T magnet is about 12 tons and its refrigeration system will be upgraded to use the new 750 W refrigerator for both cool-down and normal operation.

The interfaces between the CDB and the 45 T magnet are as follows:

- 4.5 K supply helium: This comes from the J-T stream of the 750 W refrigerator, at a flow rate of 10 g/s and a pressure of 3-12 bar. This stream is throttled and liquefied into the 4.5 K reservoir in the supply coldbox of the 45 T magnet. The He II reservoir is pumped down to 1600 Pa by a pair of Kinney vacuum pumps to get 1.8 K.

- 4.5 K helium return: This is the low pressure helium returning from the supply coldbox of the 45 T magnet.

- “20 K shield” supply: 4.5 K helium will be used for the 20 K shield cooling. The supply pressure and temperature will be the same as the 4.5 K supply helium for the coil. The flow rate is about 2.5 g/s. This stream will come from the J-T stream of the refrigerator.

- “20 K shield” return: The return helium is at about 10 K, 1.3 bar. This stream will return to the coldbox and be mixed with low-pressure return helium between heat exchangers at 10 K level.
The cooling of the “20 K shield” of the 45 T magnet is different from the current cooling method: The shield is presently cooled with 12 bar, 15 K helium at a flow rate of 2.5 g/s with a heat load on the shield of approximately 120 W. The downstream pressure and temperature is about 12 bar and 24 K. After the new refrigerator is installed, the “20 K shield” will be held at approximately 10 K.

PROJECT STATUS

The new cryogenic system design is ongoing and will be constructed in approximately two years. The helium refrigerator is in the bidding stage. The cryostat of the SCH will be installed in Cell 14 and the coldbox of the helium refrigerator will be installed in Cell 16. The first cooldown of the SCH superconducting magnet will take place at the beginning of 2012 and the 45 T hybrid will then be connected to the central distribution box.

ACKNOWLEDGEMENTS

This work is supported by the NSF Division of Materials Research through grant DMR-0603042 and the state of Florida. Mark D. Bird, PI for the SCH project, has also supported this work.

REFERENCES

The High B/T Facility opens fast turnaround 10 mK-10 T annex

In order to increase the efficiency of the Magnet Lab High B/T Facility at the University of Florida, a fast turnaround annex has been opened to allow users to test samples and experimental cells before using the high field demagnetization cryostats. The new capability is located in Williamson Hall adjacent to the Microkelvin Laboratory and consists of a high circulation rate dilution refrigerator capable of cooling to 10 mK with a heat load of 100 ergs/sec and in an applied field up to 10 tesla. The system was engineered and configured by Jian-sheng Xia and his colleagues for rapid thermal cycling from room temperature to millikelvin temperatures in as little as 24 hours.

The new capability is housed in a screened room to provide the low noise environment needed for high sensitivity measurements such as precise measurements of magnetic susceptibilities in weak magnetic systems and for transport measurements in semiconductor hetero-structures. The full suite of measurement capabilities of the High B/T Facility including ultra-low temperature thermometry, precision pressure measurements, ultrasound and magnetic resonance capabilities are available for users.

The use of the new annex is reserved for users who need to test samples or special experimental configurations prior to using the demagnetization cryostat of the High B/T Facilities. Potential users should submit a proposal for user time following the usual proposal for Magnet Lab access and are encouraged to contact Jian-sheng Xia or Neil Sullivan about their needs and available time for scheduling experiments.

Jian-sheng Xia  
(352)-392-8871  
jsxia@phys.ufl.edu

Neil Sullivan  
(352)-846-3137  
sullivan@phys.ufl.edu
Presenting the Magnet Lab’s education team

The strength of educational outreach is the people who develop and facilitate programs. The success of the Center for Integrating Research and Learning at the Mag Lab is dependent upon the commitment of everyone associated with the Magnet Lab’s outreach agenda. This issue of Mag Lab Reports provides us with an opportunity to feature the diverse group of Center educators and researchers who together form a formidable team.

**Jose Sanchez**, assistant director, is currently pursuing a Ph.D. in Teacher Education at Florida State University. His current area of research interest is teachers’ motivations to facilitate science fairs and developing best practices models for science fairs in elementary, middle and high schools. Jose’s expertise in classroom strategies combined with a deep understanding of how students learn physics provides a practical and theoretical basis for his outreach work. Jose develops and conducts teacher workshops, administers the Research Experiences for Undergraduates and Research Experiences for Teachers programs each summer, takes primary responsibility for the Magnet Lab Ambassador Program, partners with local schools and community organizations, and is closely involved in developing new programming.

**Carlos Villa**, outreach coordinator, is fully subscribed to classroom outreach through March 2010. Carlos is currently pursuing a Ph.D. in Teacher Education at Florida State University. He is responsible for all school outreach, a major portion of CIRL’s outreach efforts, which includes classroom visits, hands-on activities and tours of the lab, school-wide events, community events, and development of new outreach opportunities. Carlos fully supports all activities of the Center and is well-known among educators and the general public for providing quality experiences for K-12 students in a nine-county area in North Florida and South Georgia.

**Felicia Hancock**, program assistant, ensures that the Center keeps running at the highest level possible. She provides support for all activities, which sometimes includes taking information to schools in neighboring counties on her way home from work! Felicia is responsible for establishing the new online outreach request system that has streamlined the process and has resulted in increased outreach numbers. She schedules all tours and outreach, deals with administrative issues for the Center, including all travel, keeps the budgets, and in general makes sure all of us are supported in every way.

**Roxanne Hughes**, graduate research assistant, has been working with our programs since 2007, when she requested the opportunity to observe the SciGirls summer program. Roxanne’s major area of interest is women’s studies and researching the area of girls entering STEM fields. She has been a part of the five-year RET research project and brings a unique perspective to the Center’s work. Roxanne fully participates in all Center activities, providing outreach, participating in the Saturday Flying Circus of Physics, developing and sending surveys to teachers receiving outreach, collecting data on Center programs, analyzing the data, and serving as lead teacher for the SciGirls program. Roxanne is pursuing a Ph.D. in Educational Leadership at Florida State University.
**Kristen Molyneaux**, graduate student, is currently pursuing a Ph.D. in Educational Policy Studies at the University of Wisconsin-Madison. Her area of interest and research is free education systems in East Africa and in particular girls/women pursuing science education in Uganda. She connected with the Center after working with the SciGirls program in 2008 and provides support for all programs. Kristen is assisting with program evaluation and is developing a research project to investigate the Center’s after-school workshop model of professional development for elementary and middle school teachers. Kristen is the primary contact for external partnerships and has responsibility for collecting and analyzing data on three summer programs that are part of the Gen-III Engineering Research Centers Future Renewable Electric Energy Delivery and Management program (ERC-FREEDM) at FSU, North Carolina State University and Arizona State University.

**Brandon Nzekwe**, graduate research assistant, has worked with the Center for two years tracking REU participants, developing surveys to determine the influence of REU programs on REU students, and is currently working on a comparative study of REU programs at several universities. His work has provided a unique insight into the choices REU participants make as they pursue careers in academia and private industry. Brandon is currently pursuing a Ph.D. in Educational Psychology and Learning Systems and has been an integral part of all our programs. His current area of research interest is the professional socialization of science students.

**Pat Dixon**, director, has been with the Center for 12 years and has spent much of that time working with in-service and pre-service teachers through professional development. She oversees all programs and has primary responsibility for community and university partnerships, proposal writing and new program development. She serves on the board of two area groups: Community Classroom Consortium and Big Bend Leon Association for Science Teaching as well as on the Exhibits Committee for the local art and science museum. In addition to required administrative duties, Pat actively participates in outreach activities and conducts after-school workshops. Pat’s research interests are in the field of teacher practice – how teachers facilitate change in their classrooms – and on how informal science education affects students and teachers.
It would be an understatement to say that Robert Guertin, better known as Bob, was a frequent user at the Magnet Lab. By his own reckoning, as of November 2008, the professor of physics and former dean at Tufts University had made 56 trips to Tallahassee. The research results of loyal users such as Guertin helped build the Magnet Lab’s reputation as a scientific destination from its earliest days.

Here, colleagues and friends remember the accomplished scientist, who passed away June 12, 2009.

**George Schmiedeshoff**
Magnet Lab User
Professor of Physics
Occidental College

I first met Bob when I was a postdoc with Jim Brooks at the old Bitter Magnet Lab at MIT. Bob would jokingly characterize himself as a “dog’s ass” (Dean of the Graduate School of Arts and Sciences) at Tufts. We clearly had compatible senses of humor and quickly became friends. It might not be completely accurate to say that he “got me” my first real teaching gig, but he certainly introduced me to the physics department at Tufts and they hired me to teach a graduate level solid-state physics course. With this experience I set my sights on an academic career and have never looked back. Bob remained supportive, giving me access to his SQUID magnetometer in the days before I got a lab of my own, and we stayed in touch. Just last year he took me on a tour of barbecue “options” in Tallahassee. I feel very strongly that I would not be where I am today without Bob’s help. He was a solid physicist, an important mentor, and a good friend. I miss him.

**Joan Crow**
Center for Integrating Research & Learning volunteer
Wife of the late Jack Crow, Magnet Lab Director 1994-2004

My husband Jack and I had a long-standing relationship with Bob Guertin starting in graduate school at the University of Rochester around 1963. Students spent countless hours running experiments into the night, only to return to the lab early the next morning to begin again. This was their way of life and no one in the group ever complained of the long hours and hard work. In the next decades, Bob and Jack never lost touch even though they each went their separate ways throughout their careers. I so treasure their continued friendship.

**Some of the things I admire about Bob:**

- Men do not often make close friends, at least in my experience. With most men, I never saw the camaraderie that highlighted women’s friendships. It was different with Bob. He and Jack could joke about anything, and enjoy spending time together, plus share their vast knowledge and stages in their lives.
• Bob could be counted on to be somewhat predictable, but he always startled me with his phone calls. In Pennsylvania, he would call and without any greeting, say “Is Flash there?” In Florida, it was either “Is Budman there?” or, “Is Remi there?” He was a dog lover extraordinaire, and sometimes I accused him of visiting just to see our present dog and maybe even talk to one of them on the phone!

• Bob enjoyed telling stories about Jack. They were always shocking, and no doubt somewhat exaggerated, but that was his charm. They both played pranks on each other. Once Jack took a photo of Bob, who had worked all night on a magnet run and fallen asleep in a chair at the lab in an uncomfortable position. Jack had it blown up, sent to Bob’s office at Tufts University, and displayed prominently on his office wall. It was the first thing that greeted Bob upon his return. Bob’s favorite stories were about Jack and his propensity to snore so loudly that the whole hotel was awakened. Bob was an entertainer, a renowned scientist, a Renaissance man, a caring father and husband, and a best friend to Jack.

• After Jack’s death, Bob still came by to visit when he was running NHMFSL experiments in the cells. We would go to a local restaurant and talk about the many years we knew each other and the experiences we had. He was truly Jack’s best friend, and I’d like to feel I also had a place in this friendship. I miss him greatly.

Bruce Brandt
Former Director, DC Field Facility

Bob did his Ph.D. research under Prof. Ron Parks at the University of Rochester, as did Jack Crow and I. Bob and Jack bonded well and collaborated on research problems for many years. They also organized at least one conference that was well received. Bob and Jack were APS March Meeting roommates for many years. They teased and played practical jokes on each other from time to time.

Bob always liked parties and liked to play the piano if there was one present where the party was being held. His musical interests had a serious side too. He had season tickets to the Boston Symphony Orchestra concerts for many years.

I did not see much of Bob from the time he left U. of Rochester until I started working at the Francis Bitter National Magnet Lab at M.I.T. in 1978. He had been there for many years before me. He came to my office occasionally to chat and would announce his arrival with, “Hi. I’ve come to brighten your day!” And he did (brighten my day). He continued to brighten my day when he visited the NHMFSL in Tallahassee for his periodic weeks of research with Jack Crow, Gang Cao, Jack’s students, and, after 2005, Eun Sang Choi. He was always very generous in his mentoring and encouragement of younger scientists.

Bob was very helpful with establishing the large sample magnetometry instruments in the Magnet Lab high field facility in the early years. I often called him with questions about the more practical aspects of magnetometry in high fields and appreciated his advice. Bob donated a superconducting magnet with a vibrating sample magnetometer installed in it to the Magnet Lab in 2005. The Magnet Lab got a useful system for visitors and resident scientists to use, and Bob got to come use it without having to pay for the liquid helium to keep it cold.

Bob continued to come to Tallahassee after being diagnosed with cancer. He was too ill to make his regular trip this spring. Bob won’t appear in my office door anymore, but memories of him still brighten my day from time to time.

Eun Sang Choi
Assistant Scholar/Scientist, DC Field CMS

I don’t remember exactly how I first got acquainted with Bob. When I was working as a postdoc, I often saw him doing experiments with one of the squid magnetometers. There were cubicles surrounding the magnetometer, and Bob was taller than the average scientist. With his white hair and mustache of course, I could easily spot him, even when I was several cubicles away. It was a few years later, early 2005, that the nodding acquaintance developed into a collaborator relationship, when I helped him set up a VSM system and got involved in a pressure-dependent magnetization measurement project. Bob and I worked together running magnetic property measurements on various samples including nano biosensors, intermetallics, oxides and so forth.
Bob visited Tallahassee whenever he could find time to do experiments at the Magnet Lab. Even during his fight against cancer, he didn't miss a single opportunity of school breaks for running an experiment in Tallahassee. Bob truly loved physics and everything involved with it; doing experiments, teaching, discussion with colleagues. During each visit, Bob generated a thick notepad full of lab logs, lecture notes and new ideas.

Bob was a person of great personality as well. Full of humor and a wide knowledge of virtually everything, Bob had an ability to make the long hours of running experiments more enjoyable. I learned from Bob not only the pressure effect on magnetism, but also how the Janis Research Company got its name. He insisted on me visiting his lab, kindly offering to let me stay in his apartment located near Fenway Park for staying. Unfortunately, I couldn't make the trip, which was about moving some of his instruments to the Magnet Lab for my research.

Two months later, after Bob missed the latest APS March Meeting (which had happened only twice before during his entire career), he sent me an e-mail with updates; marriage with June and a paper we were preparing. It became the last e-mail from him. I regret now not calling him for congratulations instead of just replying to the e-mail. Despite a generation gap in age, Bob was more a friend than a senior colleague to me, which I would have never imagined under the culture I am from. It was less than 5 years of friendship but I feel the loss of a long-time friend.
People

Former user Patricia Alireza (University College of London) is one of the winners of the 2009 L’Oréal UNESCO UK and Ireland For Women In Science Fellowships, awarded to outstanding women scientists in the early stages of their career to enable or facilitate promising scientific research.

Alireza said: “I am hoping to use the prize money to finish setting up the high pressure laboratory in UCL and to continue with research I have started in collaboration with the University of Cambridge. The project focuses on studying the electronic interactions of materials under extreme conditions of pressure, low temperature and high magnetic fields in order to further our understanding of the fundamental properties of matter.”

The fellowships, which are worth £15,000 each, are awarded annually by L’Oréal UK & Ireland with the support of the UK National Commission for UNESCO, the Irish National Commission for UNESCO, the Royal Institution of Great Britain, and the UK Resource Centre for Women in Science, Engineering and Technology to promote, enhance and encourage the contribution of women pursuing their research or academic careers in the UK or Ireland in the fields of the life and physical sciences.

NMR User Program Director Tim Cross has received a $3.1 million grant from the National Institutes of Health as part of a $9 million Program Project Grant that Cross is heading up. In addition to Cross and Bill Brey at the Mag Lab, four other institutions are involved in this collaborative project including the University of Alabama, the Burnham Institute, the University of California, San Diego, and Harvard University. This group will be working on the structural and functional characterization of novel potential drug targets in the fight against tuberculosis that annually kills nearly 2 million people worldwide. In addition, the researchers hope to develop new drug screening tools to identify initial lead compounds for the pharmaceutical industry. The research will take advantage of the high field NMR facilities at the Mag Lab and at UCSD, as well as the NMR instrumentation development groups at the two institutions. Cross and his colleagues have been studying TB for about 7 years.

James H. Dickerson, an assistant professor in the Department of Physics and Astronomy at Vanderbilt, is spending from September 2009 through February 2010 working with DC User Program Director Eric Palm at the Magnet Lab. He is learning about the magnetic and magneto-optical characteristics of ultra-small europium sulfide nanoparticles. The goal of these studies is to investigate the correlation among the size of a nanoparticle, strain and surface energy-dependent affects on the atomic arrangement, and the magnetic and magneto-optical properties of the nanomaterials.

Huan He, a postdoctoral research associate in the ICR Program at the Magnet Lab, has received a Human Proteome Organization (HUPO) Young Investigator Award in the Stem Cell Proteome Biology category. She received a certificate and $500 at the HUPO VIII World Congress in Toronto in September, 2009, where she presented a talk, “Application of FT-ICR MS in a Glycomics Approach Toward Understanding Cancer Stem Cell Differentiation.” Her award is one of 21 for U.S. scientists under age 36.
Roxanne Hughes and Kristen Molyneaux, graduate research assistants with the Mag Lab’s Center for Integrating Research and Learning, will be presenting academic papers at the following conferences during the 2009-2010 academic year: National Association of Research in Science Teaching, Association for Science Teacher Education, Research on Women and Education, Florida Educational Research Association and the Eastern Educational Research Association. Papers to be presented include: The Effects of an All-Girls’ Science Camp on Middle School Girls’ Perceptions of Science and the Nature of Science, Secondary School Female Students Views of the Nature of Science: A Comparative Study of Ugandan and American Women, and The Impact of Scientist Mentors on Science Teachers’ Perceptions of Science.

Yoshimitsu Kohama and Oscar Ayala Valenzuela have joined the Pulsed Field Facility as Los Alamos National Lab Postdoctoral Research Associates.

Kohama initially came to the Pulsed Field Facility in early 2008 as a visitor, shortly after obtaining his Ph.D. from the Tokyo Institute of Technology (TiTech) under the supervision of Prof. Tooru Atake. Kohama’s year-long visit at LANL was jointly funded by a fellowship from the Japanese government and the Magnet Lab’s visitor program. Kohama joined Marcelo Jaime’s team working in the development and application of calorimetric techniques at high magnetic fields. In parallel with these activities, Yoshimitsu also completed a number of high-field transport experiments in pnictide samples made at Prof. Hosono’s lab, TiTech, Japan. Kohama’s present interests include high temperature and other novel superconductors, field induced magnetism in quantum magnets, thermoelectric materials and the development of an AC-calorimetry technique suitable for pulsed magnets.

Valenzuela was first involved in a collaboration project at the Pulsed Field Facility in early 2008. The work was initiated by his supervisor, Jose Matutes Aquino, from the Centro de Investigacion en Materiales Avanzados (CIMAV), Chihuahua, Mexico, with the goal of studying the coexistence of superconductivity and ferromagnetism in Ru-based high temperature superconductors. During his year-long visit to LANL, partially funded by CIMAV and the Magnet Lab’s visitor program, Oscar joined Ross McDonald’s team working in the development and application of ESR/EPR techniques for high magnetic fields. Valenzuela now investigates the electromagnetic and quantum properties of field-induced magnets, frustrated magnets and superconductors at very high magnetic fields.

The Applied Superconductivity Center at the Mag Lab has received $1.2 million in funding from the U.S. Department of Energy (DOE) to understand and enhance BSCCO-2212. The grant is part of a larger $4 million award over two years to the Very High Field Superconducting Magnet Collaboration, for which David Larbalestier and Alvin Tollestrup (Fermilab) are the principal investigators.
NAME:
Yury O. Tsybin

POSITION:
Tenure-track assistant professor of physical and bioanalytical chemistry, Biomolecular Mass Spectrometry Laboratory, Institute of Chemistry and Chemical Engineering, School of Basic Sciences, Ecole Polytechnique Federale de Lausanne, Switzerland

TIME AND ROLE AT THE MAGNET LAB:
June 2004-Aug. 2006, postdoctoral research associate in Alan Marshall’s lab

CURRENT WORK:
Since the move to Europe in 2006, Tsybin has continued to work in the highly interdisciplinary field of Fourier transform ion cyclotron resonance mass spectrometry, pioneered by Alan Marshall. Tsybin and his colleagues have built and support a unique-for-Europe, custom-designed 12 tesla hybrid FT-ICR mass spectrometer.

IN HIS OWN WORDS:
My group’s main research interests, both fundamental and applied, relate to anhydrous (bio) macromolecular structure and inter/intra-molecular energy relaxation pathways elucidation by FT-ICR MS based pump-probe techniques. We consequently and simultaneously use IR, UV, visible light lasers and low energy electrons to pump energy into the biomacromolecular ions in the gas phase and then probe the conformational and radical properties changes by monitoring the dissociation reaction products.

HOW HAS THE MAG LAB SHAPED YOUR SCIENTIFIC CAREER?
The taste of basic science research discoveries and the encouraging environment in the ICR group shaped my vision on the feasibility, appropriateness and excitement of academic-based carrier prospects. As a result — a faculty position in a university!

WHAT’S THE MOST IMPORTANT LESSON YOU LEARNED?
Nowadays, we find ourselves under a continuously growing press of a vast number of scientific papers published in a rapidly increasing number of journals. Conferences that are more easily reached today than a decade ago, plus frequent deadlines for abstracts/funding applications complemented by financial support dependence on the citation indexes, impact factors and h-numbers, force many scientists to publish papers that still require verification or additional support data. However, the work ethic in Alan’s group is strongly regulated by reporting only the research results that can be reproduced by other scientists both in the group and outside it. Although I’ve always been taught this way, the research environment at the Magnet Lab has strengthened this point even further.

HOW MENTORS MAKE A DIFFERENCE:
When you speak about Alan’s group, it is easier to name a few persons from whom I learned a lot, than a single one. Particularly, I was very much impressed and influenced by the professional scientific behavior of Chris Hendrickson. Chris always carefully listens to your question or a problem and takes time to think before he gives to you the reply that is well-structured and that gets to the point.

Alan Marshall is a role model in not only science, but also personal relations and group management in the ICR group. Alan’s work style, or more appropriately a work-based lifestyle, is not an easy one to copy and follow; one would need a lot of encouragement, dedication and sacrifice. I am trying.
The Magnet Lab is continually accepting proposals from interested potential users. Explore our user programs virtually at http://www.magnet.fsu.edu/usershub/

The National High Magnetic Field Laboratory is a national resource that centralizes the country’s greatest magnet-related research tools, resources, and expertise. This approach is efficient and cost-effective, and encourages fruitful, collaborative research — across disciplines — at the highest level. The Magnet Lab’s flagship magnets, designed and built in-house, are unrivaled anywhere in the world, and lab engineers are constantly striving to push fields higher still. But it’s not only the magnets that pull in upwards of 1,000 researchers each year; it’s also the world-class scientific support available at the Magnet Lab. The lab’s scientists and technicians develop the experimental instrumentation and techniques.

To learn more about a specific program of interest, contact one of the following:

**Advanced Magnetic Resonance Imaging and Spectroscopy**
Gainesville
Joanna Long
jrlong@mbi.ufl.edu

**High B/T**
Gainesville
Neil Sullivan
sullivan@phys.ufl.edu

**DC Field**
Tallahassee
Eric Palm
palm@magnet.fsu.edu

**Ion Cyclotron Resonance**
Tallahassee
Alan Marshall
marshall@magnet.fsu.edu

**Electron Magnetic Resonance**
Tallahassee
Stephen Hill
hill@phys.ufl.edu

**Nuclear Magnetic Resonance**
Tallahassee
Tim Cross
cross@magnet.fsu.edu

**Pulsed Field**
Los Alamos
Jonathan Betts
jbbetts@lanl.gov

---

![Image of lab equipment and users](image-url)