DDF annual report

Title of Investigation:

$YBa_2Cu_3O_y$ Joints

Principal Investigator:

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Other In-house Members of Team:

Theo Muench (Code 552), Dr. Ed Canavan (Code 552), Dr. John Panek (Code 552), Serena Eley (Code 552-NASA Academy), Dr. Todd King (Code 541)

Other External Collaborators:

None

Initiation Year:

FY 2005

Aggregate Amount of Funding Authorized in FY 2004 and Earlier Years:

$0

Funding Authorized for FY 2005:

$75,000

Actual or Expected Expenditure of FY 2005 Funding:

$57,000

Status of Investigation at End of FY 2005:

Will use the tools and knowledge gained from the 2005 DDF to work on the 2006 DDF on "High Temperature Superconducting YBCO Magnets."

Expected Completion Date:

September 2006

Purpose of Investigation:

High-temperature (-253°C to about -135°C) superconductors were discovered in the 1980s. However, their use has had to await the development of basic requirements, including more capable methods of permitting superconducting currents to flow from one material to another. This project is addressing that issue. It is searching for a reliable method of getting superconducting current from one piece of a high-temperature superconductor, known as YBCO, to another by a sophisticated analogue to soldering. The method is called diffusion bonding.

In more technical language, this investigation was performed to demonstrate for the first time Yttrium Barium Copper Oxide (YBCO) thin film superconducting joints that can carry a measurable critical current. Diffusion bonding is being used to demonstrate this superconducting joint between YBCO thin film samples.

Accomplishments to Date:

Because money and the full-time equivalents (FTEs) for this project did not become available until May 2005, we had only 4–5 months to work on a proposal that would have normally taken 12 months. Also, only 0.4 FTEs of the requested 0.7 FTEs were awarded. In the ensuing months, however, we made significant progress and accomplished many tasks that are pertinent to this DDF and valuable for future research in high-temperature superconductivity.

As the Code 552 superconductivity laboratory is currently being established, much of the initial time was spent acquiring the required tools and materials. After acquiring the YBCO material in the form of thin films deposited on a lanthanum-aluminate ($LaAlO_3$) substrate (Figure 1), a method was devised to cut the brittle wafers into narrow strips so that critical current measurements could be made. Figure 2 shows the two strips that will be joined. The larger strip on the right has a non-superconducting trench. Diffusion-bonded joints will be created between this strip and the smaller strip on the left to bridge this non-superconducting trench.

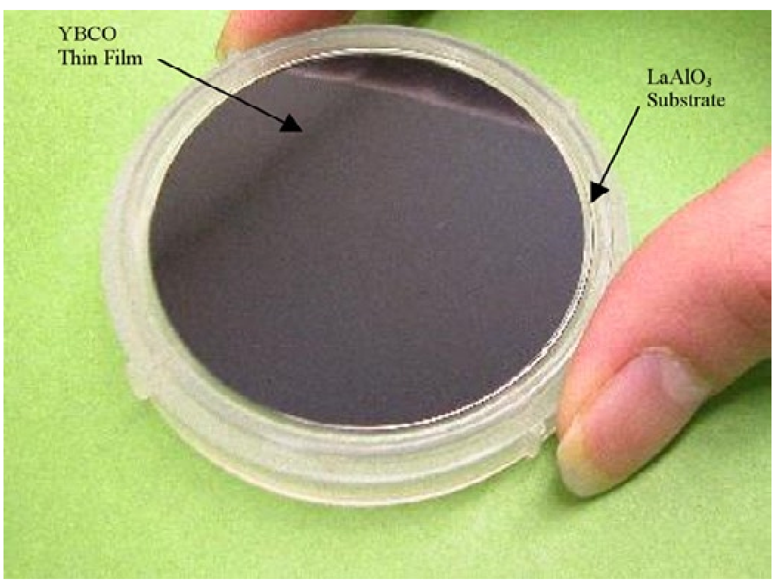

Figure 1. YBCO thin film deposited on a $LaAlO_3$ substrate wafer

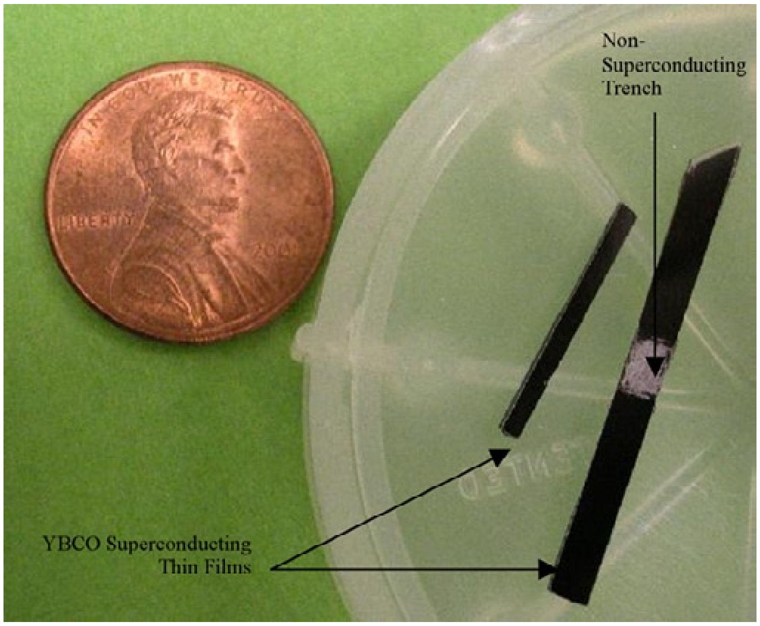

Figure 2. The YBCO wafer is diced into thin strips that will be joined

We used a scanning-electron microscope (Figure 3) and an X-ray diffraction analysis to analyze the material's surface, both giving expected results. These results will be compared with the surface analysis observations that will be made after the superconducting joints are made.

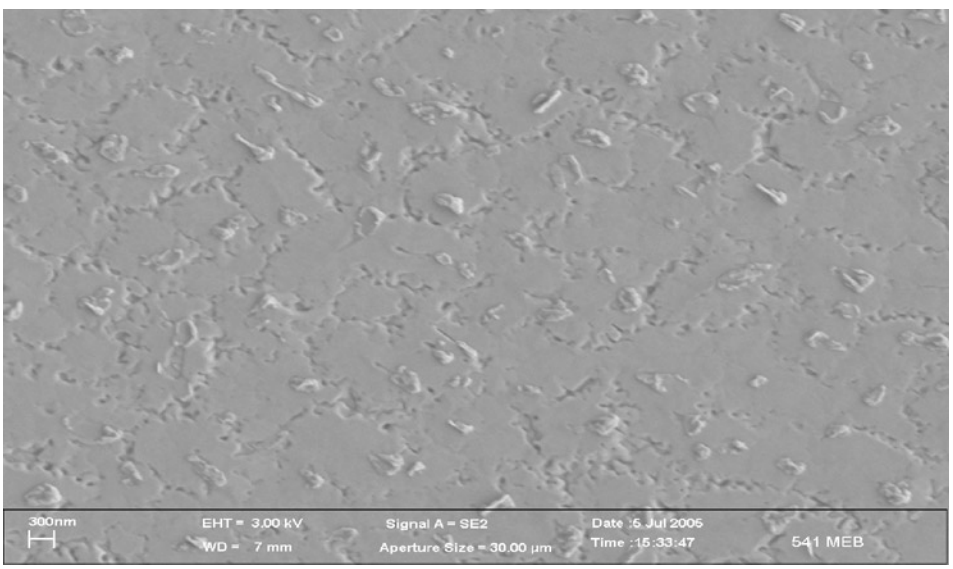

Figure 3. A scanning-electron microscope image of the surface of the YBCO thin films revealing the grain boundaries of the deposited YBCO thin film

The YBCO joints are to be fabricated by a diffusion-bonding procedure (Figure 4). This procedure involves heating the samples to a temperature of 1020°C in an oxygen-rich atmosphere. To address the safety issues involved with operating in an oxygen-rich atmosphere at high temperatures, a significant amount of time was spent implementing a safety procedure for this experiment. Work is now about to start on the diffusion-bonding process (step 4 in Figure 4). The task of demonstrating the YBCO high-temperature superconductivity joints will be continued under a related 2006 DDF to develop "High Temperature Superconducting YBCO Magnets."

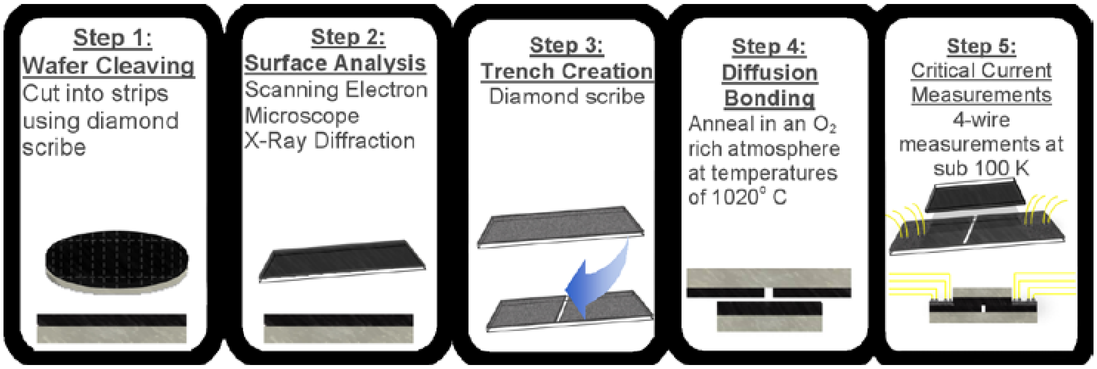

Figure 4. Procedure for creating and testing thin film YBCO joints

Planned Future Work:

Work is about to start on the YBCO joint fabrication process. Once the joints are fabricated, critical current measurements will be carried out to verify that superconductivity is maintained across the superconducting interface. The technology developed and the knowledge gained from this 5-month effort will be invaluable in the next effort to create a high-temperature superconductivity YBCO magnet.

Key Points Summary:

Project's innovative features: The important innovation would be the new methods (diffusion bonding) of making superconducting joints between thin films of YBCO superconductors. If successful, such bonds may be used to make long and or complex configurations of YBCO films on tapes or wafers, which are essential for many applications.

Potential payoff to Goddard/NASA: YBCO thin film joints will prove to be the stepping-stone for many other technologies. Many high-temperature superconductor devices will need superconducting joints to interface between components and devices. A few of the technologies that might develop from research on YBCO joints and their relevance to Goddard and the Space Exploration Initiative are:

- The Continuous Adiabatic Demagnetization Refrigerator (CADR). This is ideal for cooling detectors that are used to observe X-ray and Infrared sources. YBCO magnets would enable the high-temperature end of the CADR to be directly connected to radiators, which expel heat directly into space, without the need for intermediate cooling devices. YBCO also is ideal for superconducting magnetic bearings on vibration-sensitive equipment. Another application for small YBCO magnets is with magnetostrictive actuators for low-temperature adaptive optics, which may fly on future infrared missions. Other applications include magnetic shielding for detectors, magnetically controlled micro-shutters, and low-temperature thermal shielding.

- The Space Exploration Initiative. YBCO thin film tapes would allow more powerful and efficient magnets for the Variable Specific Impulse Magnetoplasma Rocket, which might take humans to Mars and beyond more quickly and efficiently than current technology. YBCO magnets might provide magnetic shielding against charged-radiation particles for astronauts and radiation sensitive instrumentation on long-haul flights. Electro-Magnetic Launch Assist technologies may prove to be economically essential for launches from the Earth, Moon, Mars, and beyond. YBCO energy storage devices would provide higher round-trip efficiencies and significant mass reduction when compared with today's best batteries.

The criteria for success: The essential criterion for success is that the YBCO joints can carry a measurable critical current. A major goal of this effort will be to increase overall Goddard expertise in the area of superconductivity because the applications of superconductivity may prove to be invaluable for NASA and Goddard. Given the minimal time and reduced FTEs available, the first goal is still pending completion. However, the insights gained from the current effort will definitely be invaluable in future YBCO research efforts.

Technical risk factors: Creation of good superconducting joints is a very delicate and a highly iterative process. A good understanding of the material science of ceramics will be vital to this effort. Guidance from senior personnel in the cryogenics and materials branches will minimize these risks. The procedure for diffusion-joint fabrication involves processing the thin film in a high-temperature, oxygen-rich environment. Adequate steps have to be taken to make sure that all safety issues are addressed.