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DEVELOPMENT OF ELEMENTS OF A HIGH Tc SUPERCONDUCTING CABLE

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PROGRAM SUMMARY

The realigned program is aimed at the development of long lengths of silver-clad BSCCO. A variation on the powder in tube technique will be used to make silver-clad BSCCO tapes. BSCCO-2223 is the material of choice with 20K the operating temperature goal. Such a tape conductor ultimately could be used in a coil for a magnet, motor or generator.

A key element of the program is the development of processes with the potential of fabrication of very long conductors. A novel process for making silver clad tapes (SCT) is under study. In this process extruded BSCCO is wrapped with silver foil which is then pressure welded. This technique has the potential for fabrication of continuous lengths and also avoids the extensive size reduction and attending potential for non-homogeneity involved with the more conventional powder-in-tube (PIT) process. A parallel PIT study is also underway to use for comparison purposes and as a back-up process to the SCT process.

We are making good progress on the fabrication of BSCCO tapes. Large powder batches of 2223 are now available. We can make moderately long PIT tapes. The extrusion and silver welding processes are under study. The major problem which is now facing us is the improvement in the Jc values of the tapes. This will involve optimization of the microstructure during the deformation and heat treatment cycles.

PROGRESS

TASK 1 -- POWDER PRODUCTION

The goal of this task is the production of reproducible, large powder batches of BSCCO-2223 to be used in the tape development effort. We are using lead-doped compositions to optimize the formation of the high-Tc 2223 compound from 2212 which forms first.

We have made large batches of two different in-house powders which have slightly different compositions. In one case additional calcium and copper were added to increase the reaction rate for the formation of 2223. We have also tested 2223 powders from 3 different commercial vendors. One vendors powder can be calcined to make a high fraction of 2223. We will be studying this powder as well as the two in-house powders. Preliminary results from metallography of PIT samples show considerable amounts of non-superconducting phases. An immediate goal of this task will be to reduce the amount of these phases in the powder and to reduce the particle size of the remaining non-superconducting material.

TASK 2 -- TAPE FABRICATION USING POWDER-IN TUBE

Deformation processing of BSCCO-filled silver tubes is done by sequential swaging, drawing, and rolling. The tapes are then subjected to rolling and heat-treatment cycles under task 5 to optimize properties, especially Jc. The aim of this task is to provide materials for the Jc optimization studies as well as provide a back-up process for the SCT process.

A process for fabricating tapes has been developed. Tapes as thin as 0.1mm (0.004") have been made. We have demonstrated conversion of 110mm long powder columns in silver tubes into 2.7m long tapes 0.25mm thick. Experiments on shorter sections show these could be further reduced to 0.1mm with an expected length of about 6m. Our present processing equipment and the commercially available silver tube lengths will limit the maximum continuous lengths which we can make by the PIT process to about 15 to 20 meters.

TASK 3 -- EXTRUDED TAPE FABRICATION

A new process for the fabrication of high-Tc conductor silver-clad tape is under study. The first step is to extrude a thin tape containing BSCCO and organic binder. The tape is then placed in silver foil bent around the extruded tape but not sealed. A heat-treatment in an oxidizing atmosphere is used to remove the organics from the composite tape. This task is aimed at the optimization of the extrusion and binder removal steps.

We have demonstrated the ability to extrude 0.4mm thick BSCCO tapes using a binder system previously developed at GE for ceramic extrusion. Our screw-driven extruder has the capability to make tape continuously of any desired length. X-ray diffraction analysis of the surface of the as-extruded tape shows considerable alignment of the powder particles. Figure 1 shows a comparison of the powder and extruded tape patterns. The enhancement of the (00*l*) peaks is clear. This c-axis alignment perpendicular to the tape width is expected to improve further during subsequent rolling of the silver-clad tapes

TASK 4 -- SILVER FOIL PRESSURE WELDING

The second step in the new Silver Clad Tape process is the sealing of the edge of the silver foil wrapped around the BSCCO tape. We propose to do this using pressure welding. Silver is quite ductile and is an ideal material for deformation welding. We hope to be able to weld shut the silver-BSCCO tape by rolling the overlapped silver edges. After the tape package is sealed it will be rolled and heat-treated under task 5.

Preliminary experiments using two 0.125mm thick silver foil pieces has shown that a reduction in thickness of about 70% results in good welds. Initial sealing experiments are underway using short packages of 0.4mm thick extruded material in 0.125mm thick silver. The silver was wrapped around the tape segments and a 525C heat treatment in oxygen was done to remove the organic binders. The edges were then welded shut by cold pressing between a flat plate and a round rod. The packages are now undergoing heat treatment and deformation cycles to prepare thin tapes for Jc measurements.

TASK 5 -- SUPERCONDUCTOR OPTIMIZATION

The optimization of silver-clad BSCCO superconductors requires the correct deformation of the tape as well as optimized heat-treatment times and temperatures. These will be studied in this task for both PIT and SCT tapes. Properties to be measured will be Jc (using both transport and magnetic hysteresis measurements), flux creep, grain alignment, and microstructure. Initially we are using transport Jc measured as a function of temperature with no applied field as a measure of sample quality.

We have just begun work on this task using the PIT tape samples. We know that improvement in the Jc values will require good alignment of the grains as well as good phase purity and high density. Although there is some information in the literature on heat treating cycles, this task will of necessity involve many iterations to determine the best set of processing parameters.

Measurements of Jc for one set of samples as a function of temperature are shown in Figure 2. The two data sets are for a PIT material which was rolled to a thickness of 0.18mm and then heat treated at 845C for 25 hours or 75 hours. The Jc values as a function of temperature with no applied field are shown in Figure 2. It can be seen that the additional heating time had no effect on the Jc. Similar experiments are underway looking at heat treatment times/temperature cycles as well as the deformation history of the samples.

TASK 6 -- LONG LENGTH AND SINGLE COIL PROPERTIES

The properties of long lengths of tape will be studied when the Jc of short sections has been improved. The uniformity of properties along the tape are particularly important. The effect of winding the tape into a pancake coil configuration will also be studied.

Equipment and techniques are available for the characterization of single layer or multilayer small coils as a function of both temperature and applied magnetic field.

TALKS AND PAPERS

K W Lay, "Critical Currents in Aligned YBCO and BSCCO Superconductors", Invited talk given at New York State Institute on Superconductivity Conference, Sept.20, 1990, Buffalo, NY To Appear in Conference Proceedings

GOALS FOR NEXT QUARTER

Reduction in amount and size of non-superconducting phase in powder

Continue fabrication of PIT tape

Determine time and temperature for binder removal from extruded tape.

Continue pressure welding short sections of SCT BSCCO-Ag composite

Continue study of factors influencing Jc of PIT tapes

FINANCIAL STATUS

All values are cost plus fixed fee total costs.

TOTAL FUNDING REQUIRED FOR EFFORT 01Sept88 through 31Aug91 (36 months)	$2,424,530
CURRENT AUTHORIZATION 01Sept88 through 31Jan91 (29 months)	1,668,000
FUNDING EXPENDED TO-DATE 01Sept88 through 30Sept90 (25 months)	1,267,803

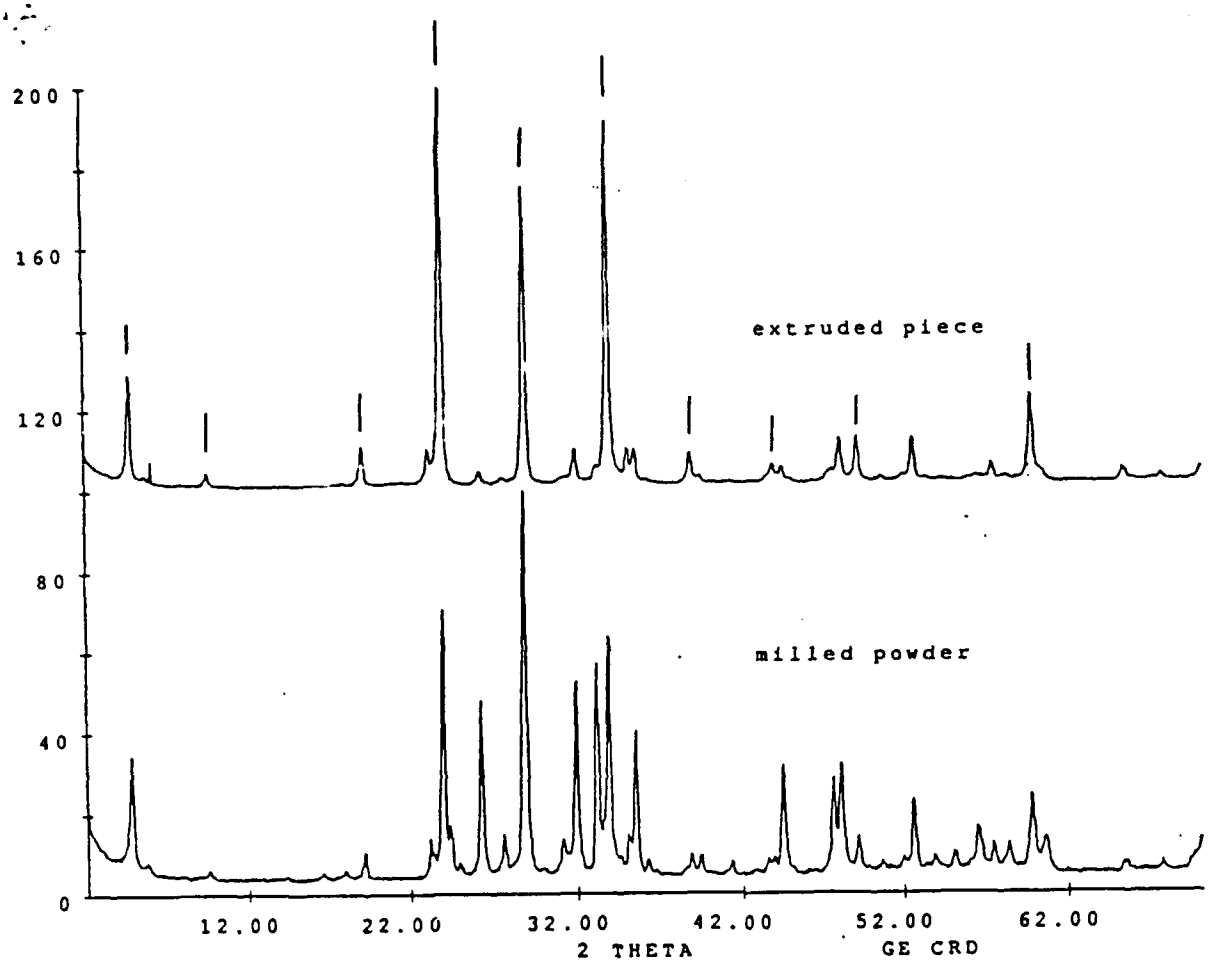

Figure 1 *Demonstration of improved alignment of extruded tape.* Marked peaks are (00*l*).

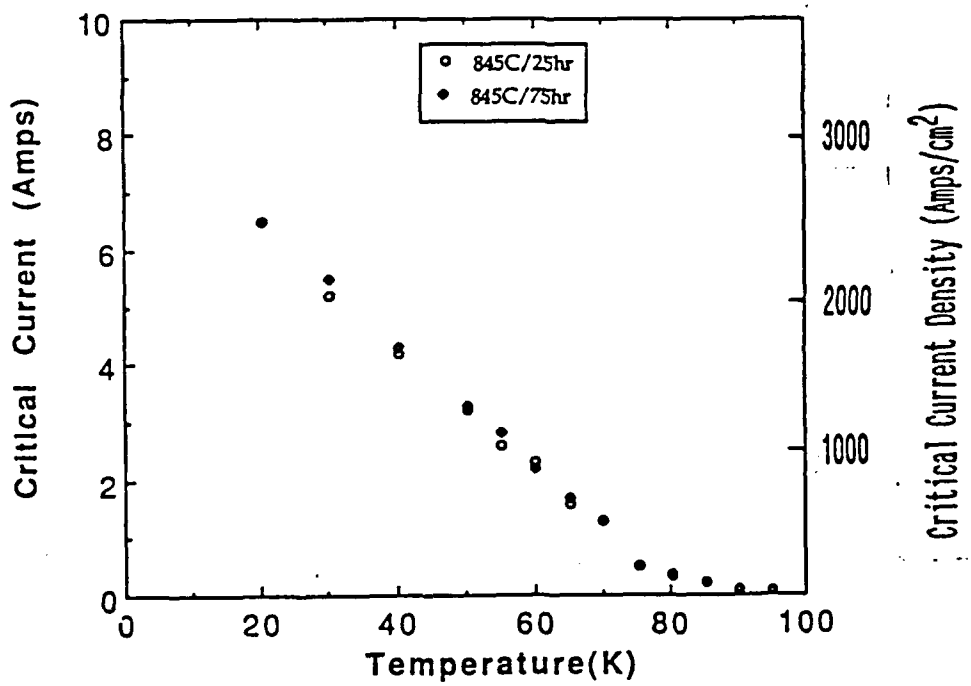

Figure 2 Critical current of BSCCO-in-silver tape. Total tape thickness = 0.18mm, Jc is calculated for BSCCO cross section.