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Experiments on large single crystals of the superconducting oxides YBa2Cu3O7, La2-xBaxCuO4 and Bi - Ca- Sr - Cu-O

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The growth and characterization of single crystals of the high temperature superconductors was investigated. High temperature, high pressure annealing of crystals of YBCO was carried out and found to be ineffective in further raising the Tc of the crystals beyond 93 K. Torque magnetometry measurements on YBCO crystals showed that the coherence length anisotropy is 5.5, independent of temperature in the range 80 to 90 K. The growth of the "40 K" system based on LaCuO doped with Ba, was attempted. Large crystals were obtained, but the Ba content (x approx. 0.5) was too high to sustain high temperature superconductivity.

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Experiments on Large Single Crystals of the Superconducting Oxides $YBa_2Cu_3O_7$, $La_{2-x}Ba_xCuO_4$, and Bi-Ca-Sr-O

The optimization of crystal growth of $YBa_2Cu_3O_7$, using a novel flux method was carried out. The crystals were characterized by transport and magnetization measurements. The growth technique was also extended to the "40 K" system $La_{2-x}Ba_xCuO_4$, but the Ba content of crystals grown was too high for the appearance of superconductivity.

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Title: Experiments on Large Single Crystals of the Superconducting Oxides $YBa_2Cu_3O_7$, $La_{2-x}Ba_xCuO_4$, and Bi-Ca-Sr-O

Conditions of the award: Prior to the contract award the Principal Investigator and a colleague (Dr. Z.Z. Wang) had discovered a non-equilibrium flux technique to grow single crystals of the superconductor $YBa_2Cu_3O_7$. Large superconducting crystals with transition temperatures Tc between 90 and 93 K were routinely attained. The crystals have the desired superconducting properties as grown, and no post-annealing is required. The original intent of the project was to carry out a number of specific physical measurements as described in the submitted proposal to characterize the crystals and to further optimize the quality of the samples. However, shortly after the award was granted, the contract monitor terminated the contract because of a perceived strong overlap with a project funded by the Office of Naval Research. (The proposal submitted to the AFOSR actually has very little overlap with the ONR project except for one experiment (out of 7) on thermal conductivity. Both projects are for studying superconductivity phenomena in single crystals of the high Tc oxides using *different* experimental approaches.)

As a result of the termination, only $ 25, 531 was awarded out of the original $ 100,803 granted. This effectively terminated the program as originally described in the submitted proposal. The following report describes the work performed with the funds available.

Accomplishments:

1) High pressure oxygen treatment of $YBa_2Cu_3O_7$ crystals. A high pressure system was constructed to investigate the effect of oxygen post-annealing $YBa_2Cu_3O_7$ crystals in pressures up to 20 bars and temperatures up to 500 C. It was found that high-pressure, high-temperature annealing had a deleterious effect on the sharpness of the transition (at 90 K). In contrast to the findings of other groups that oxygen post-annealing raised the Tc of their crystals, our finding is that with sufficiently high quality crystals with Tc exceeding 90 K as-grown, further post-annealing either leads to no changes or a to a slight degradation in the sharpness of the transition. We have also tried post-annealing at 70 C for three days, and found little change to the resistivity of the crystals. An unsuccessful search was made for anomalies in the resistance near 240 K in these annealed crystals.

2) Torque Magnetometry of crystals. A torque magnetometer was constructed and used to measure

the torque of single crystals of $YBa_2Cu_3O_7$ in the temperature range 80 to 90 K in fields up to 1 T. Extensive measurements were made of the temperature dependence of the torque vs. θ curves (where θ is the angle of the magnetic field B to the sample c axis). The data are consistent with a coherence length anisotropy of 5.5 in $YBa_2Cu_3O_7$, independent of temperature. This number compares well with estimates based on direct imaging of penetration depths made by Dolan et al. Jumps in torque vs. θ curve were also observed when **B** is almost parallel to the CuO_2 planes. These jumps were interpreted in terms of locking of the vortex lattice to principal crystal axes when **B** is rotated.

3) Growth of $La_{2-x}Ba_xCuO_4$ crystals. The crystal growth technique was adapted to synthesize crystals of $La_{2-x}Ba_xCuO_4$. Fairly large crystals (0.5 x 0.5 mm^2 in area) were obtained. However, these crystals have a high Ba content ($x \approx 0.5$) and are metallic. No superconductivity was detected in these samples. Although the program's termination stopped work in further investigation in this direction, there is significant promise that if the Ba content can be lowered by a factor of 2, superconducting crystals of high quality can be grown.

Publications:

"Torque measurements of the coherence length anisotropy in single-crytals of $YBa_2Cu_3O_7$", T.R. Chien, Z.Z. Wang and N.P. Ong, to be published.

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