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Simple Instrumentation for Testing of Ceramic Superconductors*

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SIMPLE INSTRUMENTATION FOR TESTING OF CERAMIC SUPERCONDUCTORS

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ABSTRACT

In order to compare procedures for fabricating $YBa_2Cu_3O_{7-x}$ samples in a fast and convenient way we have used two inexpensive devices: a rather sensitive pendulum for indication of the amount of superconducting phase in the sample and a transformer for the measurement of critical current. Both devices are described in detail.

INTRODUCTION

Recipes for making high critical temperature superconducting oxides, are given in the carefully written pioneer paper of Bednorz and Muller[1] and the breakthrough paper of CW Chu et al.[2] The exact chemical composition of the superconducting phase Y $Ba_2Cu_3O_{7-x}$ was revealed in the March 18, 1987 meeting of the American Physical Society and first published by R.J. Cava, et al.[4] In the process of reproducing these results and optimizing the fabrication procedure for producing samples of this material with maximum Meissner effect and critical current at liquid N_2 temperature, we built two rather simple devices: A Meissner effect pendulum and a critical current transformer.

THE PENDULUM

The pendulum[5] consists of a basket weighing 0.28 g hanging from an 3.657 m long thread protected from wind drafts by an equally long 10 cm diameter tube. Two essential peripherals to this pendulum are a liquid N_2 container that can be lifted to cool the basket and a strong permanent magnet that is used to repell samples placed in the basket to a distance, d, measured against a horizontal ruler. This simple device is sketched in Fig. 1. It permits a relative measure of the repelling force on the induced

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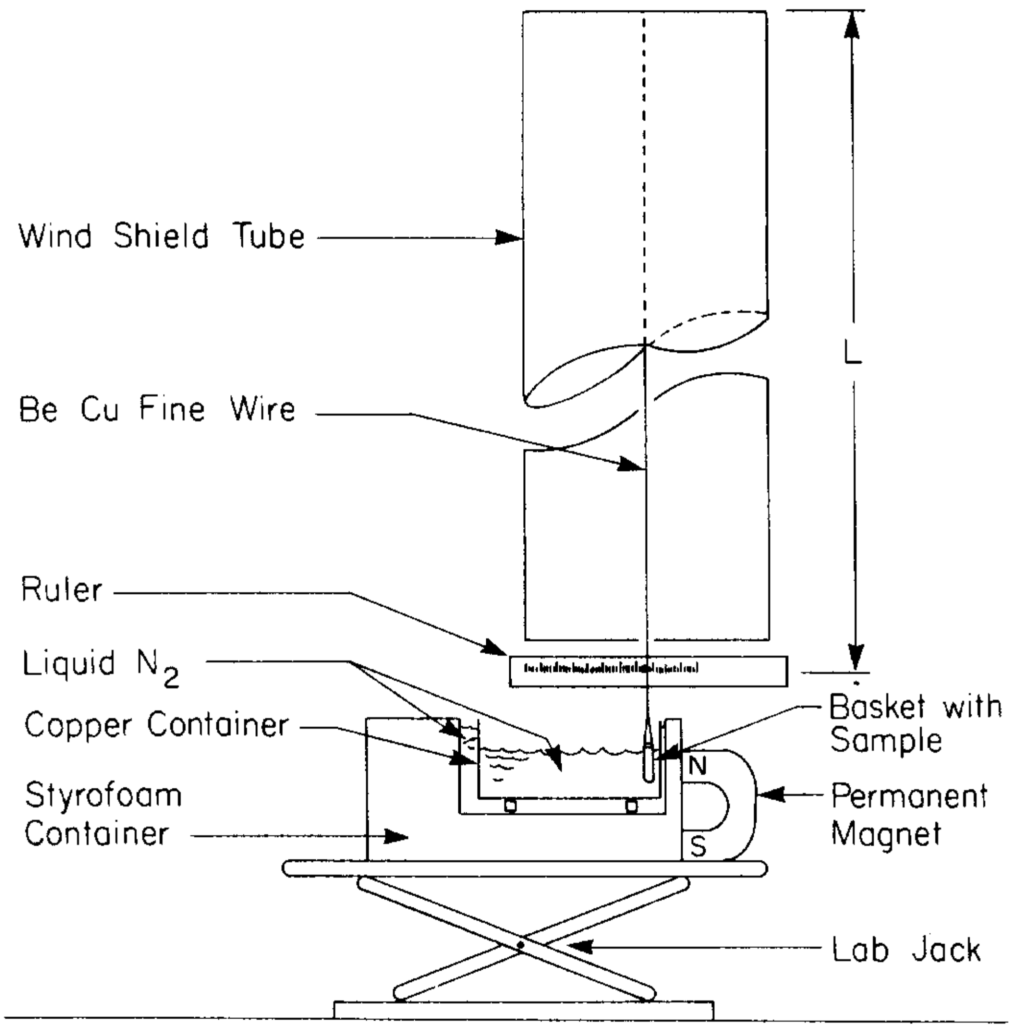

Fig. 1. Pendulum for measuring induced current repulsion force.

surface currents of different samples. The immediate and fast comparison of samples that is facilitated by this device (no need to attach leads etc.) is quite valuable for conveniently optimising the production procedure. Both solid and powder samples can be evaluated this way.

A few details of this device are: the thread is a 38 μm Be-Cu wire; the basket is made out of 38 μm thick brass foil; the windshield tube is aluminum 1.7 mm thick, and the liquid N_2 is contained in a 15.5 cm long X 5.1 cm wide X 5.1 cm deep copper-foil container installed in a 16.5 cm x 7.6 cm x 6.0 cm deep hole machined out of a 17.8 cm X 22.8 cm X 12.7 cm block of styrofoam, off center to permit the magnet outside to be no farther than 0.6 cm from the basket. The metal construction permits all parts to be electrically connected and electrostatic effects avoided. The liquid N_2 in between the styrofoam wall and the copper container prevents the liquid N_2 in the container from boiling and disturbing the stability of the sample contained in the basket repelled by the permanent magnet in its standard position.

THE TRANSFORMER

A sample of superconducting ceramic might be repelled by a magnetic field and yet have its superconducting grains so poorly connected that it presents resistance and has zero critical current. For the design of superconducting magnets we need to know the critical current at liquid N_2 temperature. The problem of attaching current leads to samples capable of carrying currents in excess of 100 A, is not a trivial one. After some attempts of casting low melting alloy leads to our original 3 mm X 3 mm X 19 mm pressed samples and considering the effects of the voltage tap positions in the meaning of the measurement[6] we decided to postpone the solution of this problem and measure the critical current in a simpler way, more appropriate to the present problem i.e.: to optimise the sample production procedure, specially the oxidation and heat treatment schedules for maximum critical current at liquid N_2 temperature. This simpler way is to make the sample in the form of a loop (more precisely, a flat washer) that fits inside a commercially available[7] ferrite-core transformer kit. This kit consists of a plastic spool form with lead posts and two identical ferrite-core forms. These, face to face, surround the spool providing a closed high permeability path for the magnetic flux lines generated by currents in the coils to be wound on the spool and the induced current in the sample washer placed alongside the spool.

Two coils are wound on the spool with fine enamel insulated copper wire: a primary with a few thousand turns and a pick-up coil with a few hundred turns. In order to allow for the thickness of the sample the walls of one ferrite-core form have to be extended. This can be done by grinding away the base of a third ferrite-core form and gluing the left over walls with 5-minute epoxy. The circuit used is shown in Fig. 2. The details of the actual transformer are: a primary with 1710 turns, 14.8 Ω at 77 K, 150 mH and a secondary pick-up with 78 turns, 0.8 Ω at 77 K, 0.300 mH. Both coils wound with enamel insulated copper wire 0.127 mm thick. The typical superconducting ceramic sample has to have an I.D. larger than 11.3 mm and an O.D. less than 20.8 mm and a thickness less than 0.2 mm unless the extension described above is made to the ferrite-core walls.

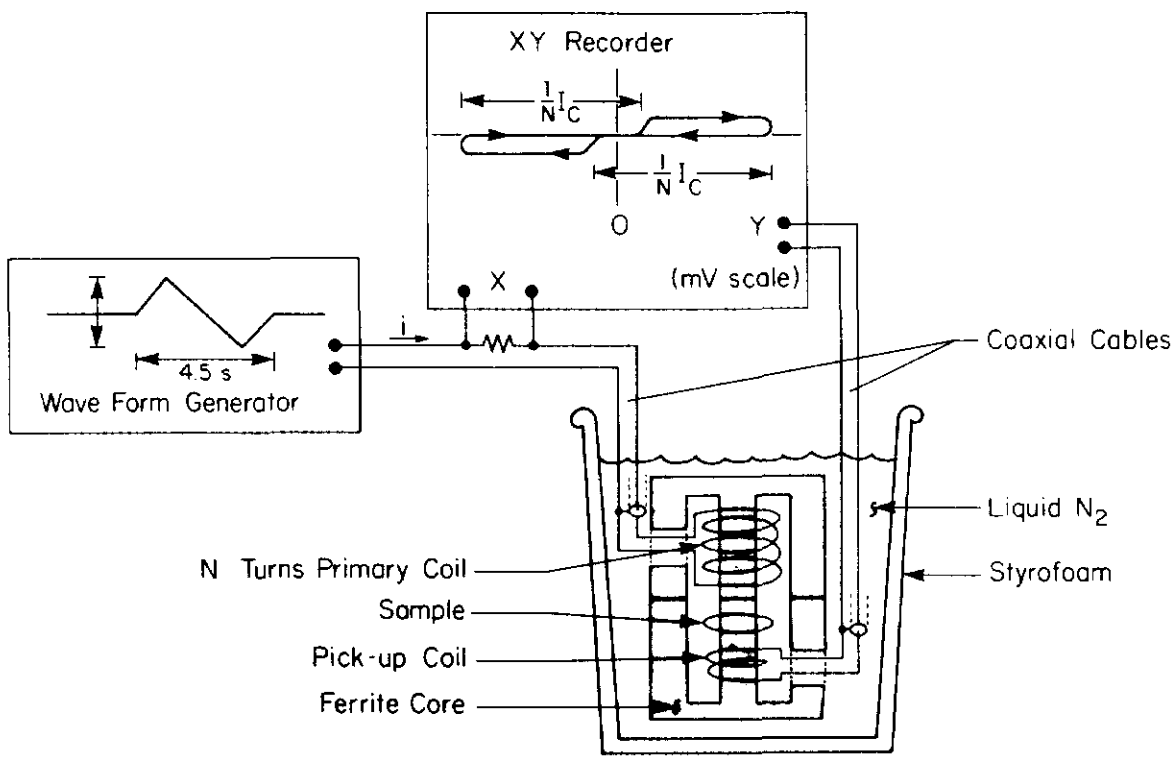

Fig. 2. Setup for measuring critical current.

The sample washer when superconducting acts as a shorted one turn secondary winding. The rather perfect magnetic coupling of these windings due to the ferrite-core causes the transport current induced in the superconducting washer to be equal and opposite to the current flowing in the primary times the number of turns of the primary. The result is no signal in the pick-up coil. When the superconducting current reaches its critical value the washer becomes resistive and the pick-up coil shows a signal proportional to the time derivative of the magnetic flux now changing in the ferrite-core.

To excite the primary we use single cycles of triangular wave. This causes a constant positive or negative voltage in the pick-up coil when the washer is not superconducting, and permits us to distinguish the first cycle from the others in a series of repetitive cycles. This history dependent performance is due to trapped flux. An x-y recorder with the x axis measuring the current through the primary and the y axis indicating the voltage in the pick-up coil is used to observe and record the measurement. Typical data taken with a 4.5 s cycle time and several amplitudes is shown in Fig. 3. With a typical electronic signal generator and using rather thin copper wires we can test samples for critical currents of the order of hundreds of amperes. The second and best sample we have tested so far, went normal with 6A, its 1 mm X 4 mm cross section yielding a not impressive 1.5 A/mm^2 average critical current density at essentially 0 Tesla and 77 K.

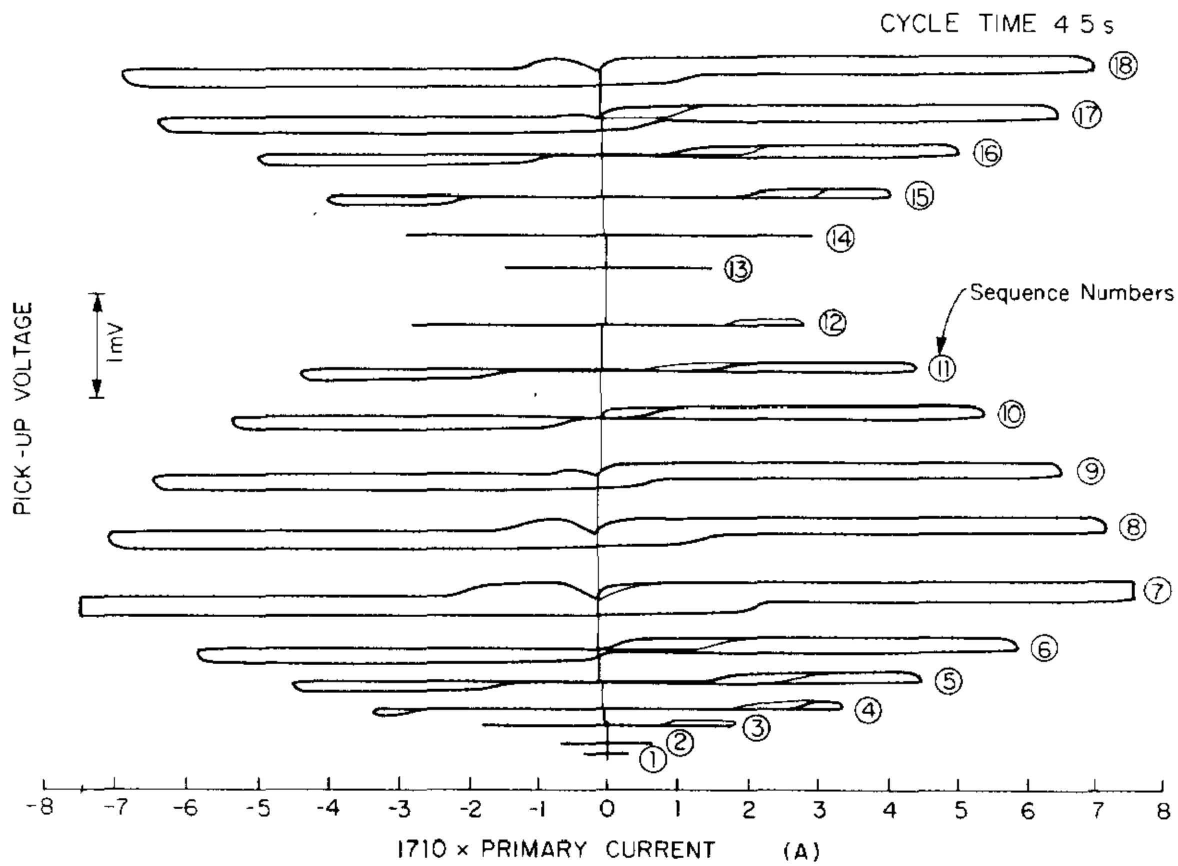

Fig. 3. Sequence of typical critical current data.

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4. R.J. Cava, B. Batlogg, R.B. Van Dover, D.W. Murphy, S. Sunshine, T. Siegrist, J.P. Remeika, E.A. Rietman, S. Zahurak and G.P. Espinosa, Phys. Rev. Lett. 58, 1676 (1987).

5. We acknowledge A.V. Tollestrup for this suggestion.

6. We acknowledge conversation with Z.J.J. Stekly to this effect.

7. Ferrite Pot Core series 2616P-A1000-3B7 with Bobin 2616PCB1 manufactured by Ferroxcube - Div. of Amperex Electronic Corp., Saugerties, N.Y. 12477 - Tele. (914)246-2811.