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THE MAGNITUDE OF THE MAGNETIC FIELD NEAR THE SURFACE OF A HIGH-T_C SUPERCONDUCTOR WITH A TRAPPED FLUX

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In 1986, much excitement was caused by the discovery of a class of materials that conducted electricity with zero resistance at temperatures above the boiling temperature of liquid nitrogen. This excitement was checked with the difficulties of manufacturing ceramics and the usefulness of these high temperature superconductors restricted by their becoming high resistive conductors at small current densities. A lack of pinning of the magnetic field flux caused the return of high resistance as the current was increased in these materials. A study of the magnetic field near the surface of a high temperature superconductor is a first step in the search for a means of pinning the flux lines and increasing their critical current densities.

A review of magnetic field sensor technology[1,2] list the following magnetic sensor technology: Search coil magnetometer, flux gate magnetometer, Optically pumped magnetometer, nuclear precession magnetometer, SQUID magnetometer, Hall effect sensor, magnetoresistive magnetometer, magnetodiode, magnetotransistor, fiber optic magnetometer, and magneto-optic sensor.

To obtain high resolution of the magnetic fields near a 77 Kelvin surface placed constraints on the technology that could be used. A search coil was built with a 10-turn loop that was 1 mm in diameter and on the end of a ceramic shaft. Electrical contact was made by grinding notches in the ceramic shaft and winding the ends of the coil leads around the shaft. Gold brushes were needed and a dentist drill technique was to be used to spin the coil 100,000 rpms to detect magnetic fields of 1 gauss. This technique was abandoned as the ceramic shaft shattered even at modest rpms.

Charles Sisk scanned the surface of the superconductor with a small magnet attached to a rod which was connected to a strain gauge. He measured the force on a 0.01 mm^2 magnet near the surface. This force was proportional to the gradient of the magnetic field. He also scanned with a loop of wire and measured the induction. He may scan again with increased resolution with a loop that is wound on an easily magnetized material. Photograph #1 is the computer generated 3D image of the magnetic force.

A Hall probe is usually used to determine magnetic field strength but they are extremely sensitive to temperature change and have a lower temperature limit of -40 ^{o}F. I used an RFL industries model 912015 flat hall probe with an active area of

0.040 inch by 0.090 inches. The claimed temperature sensitivity of 0.05%/^{o}C was checked and found to be -10%/^{o}C. To keep the temperature above -40 ^{o}F, a heater of 14 ohms was would on a ceramic shaft and a thermocouple was embedded in the probe mount to monitor the temperature of the probe. Several layers of super insulation and a nylon sheath cover was used to prevent liquid nitrogen from touching and cooling the probe. A current of 250 ma kept the probe at a temperature within 1 ^{o}C or 5 ^{o}C during the surface scan. The magnetic field was a maximum of 300 gauss which the computer generated 3-D image in photograph #2 and -100 gauss imaged off the edge of the superconductor.

A comparison between the defects in the surface of the superconductor and the magnetic field showed only a change in the field near a notch and the edge. No correlation was found between the surface grain or structure and the oscillations in the magnetic field. The observed changes in the magnetic field show resonances which may give an indication into the non-flux pinning in these superconductors. A flux pinning mechanism will increase the critical current densities, therefore, other methods of determining this field should be tried.

With a trapped flux of several hundred gauss and nanovolt sensitivity, a search coil could be used rotating at hundreds of rpms.

A flux-gate magnetometer was designed with a detector wound on a ferrite core obtained from an early computer core memory. Orthogonal windings around the ferrite core will give magnitude and direction of the magnetic field. I would like to spend this academic year building the detection circuitry and winding a 1 mm flux-gate detector and return to Marshall to scan the surface on a high temperature superconductor and obtain the magnitude and direction of the magnetic field near a high temperature superconductor.

I could also build a flux-gate magnetometer with a high-T_C superconductor pickup coil operated near H_{C2}.

REFERENCES

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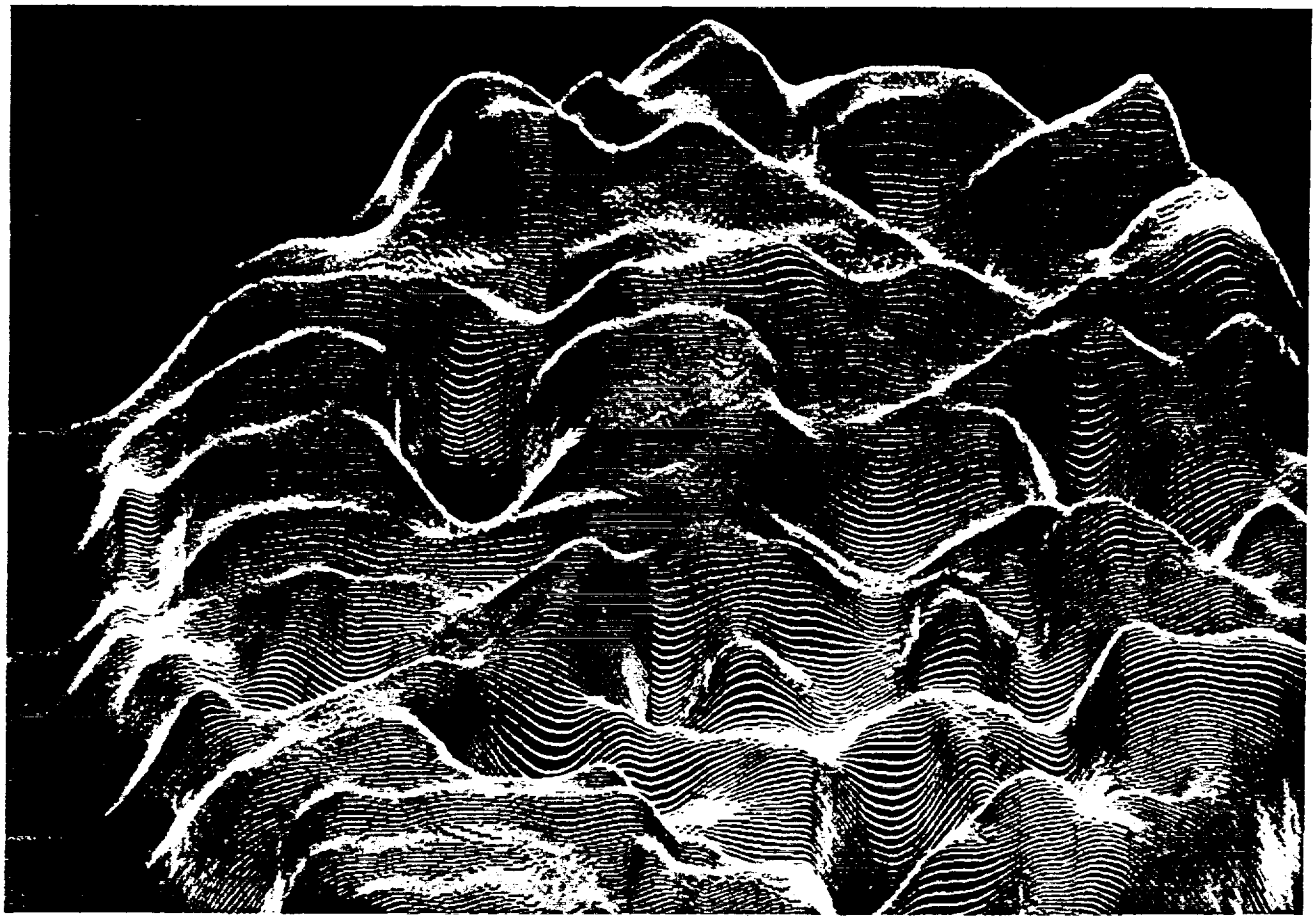

Photo #1 Computer generated 3D image of the magnetic force.

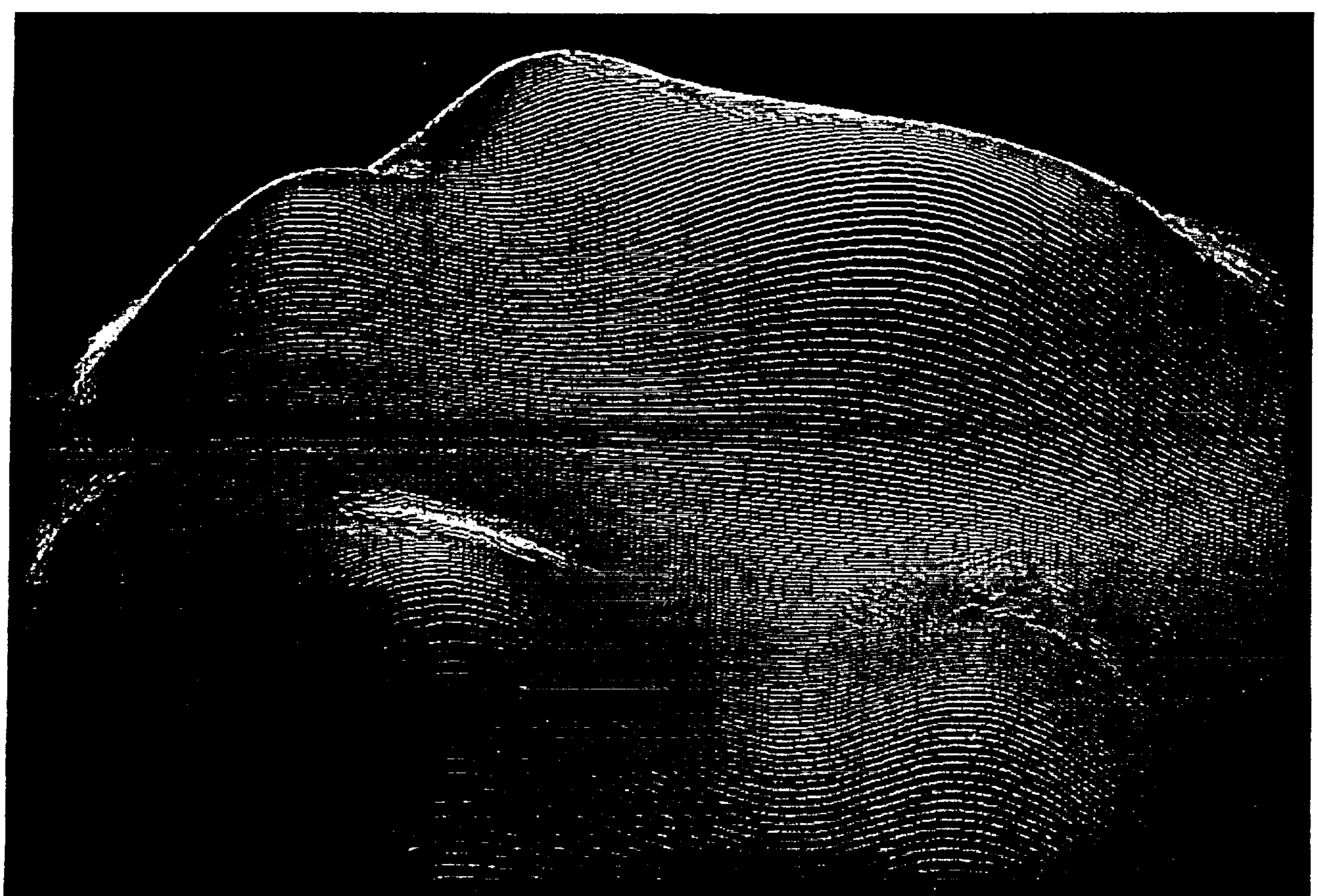

Photo #2 Computer generated 3D image of magnetic field (300 gauss)