fects of any foreign superconducting impurity. We have also detected superconductivity in powdered specimens, ruling out the possibility of a superconducting second phase. We have observed transitions in the presence of applied magnetic fields. Such transitions display the hysteretic behavior typical of most superconducting alloys and compounds.

Comparison of the zero-field transition observed for $Ge_{0.976}Te$ with that obtained for a geometrically identical sample of Sn leads one to the conclusion that the GeTe sample exhibited complete diamagnetic shielding. The experimental accuracy on this point is approximately 5%. The observation of complete shielding constitutes merely a necessary and not a sufficient observation from which one can conclude that the entire volume of the sample has entered the superconducting state Keeping in mind this limitation of the data, we feel that the superconductivity of GeTe is as firmly established as is that of most other superconducting alloys and compounds.

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SILSBEE-LIMIT CRITICAL CURRENTS IN A 1700Å FILM OF TIN

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Reported in this Letter are some new pulse measurements of critical currents obtained from an evaporated film of tin whose thickness was 1700 Å. The current pulse amplitudes required to induce 90% of the normal film resistance within the observed response time of the equipment are in good agreement, over a wide temperature range, with the Silsbee hypothesis for bulk tin, if latent heat effects are taken into account. Film imperfections, coupled with Joule heating in pulse measurements, have apparently limited previous measurements [1-8] to values substantially less than the Silsbee limit even when the films were sufficiently thick so that the Silsbee value should have been applicable.[9] Joule heating effects have been reduced in the results reported herein by using current pulses less than 10^{-9} sec in duration, compared to the $\geq 10^{-8}$ sec used earlier.[2,6,7]

Only a brief description of the experimental arrangement will be given here. The film of tin was evaporated onto a rapidly rotating (1800 rpm) hollow glass tube at about 1000 Å/sec in a vacuum of about 5×10^{-6} Torr. The thickness was determined from the temperature-dependent part of the resistance.[10] The superconducting transition temperature and transition width were 3.76°K and 0.017°K and were obtained with a measuring current of 10^{-2} A. The residual resistance was 0.029 of the room temperature resistance. Sondheimer's results[11] indicate that this residual resistance arises predominantly from electronic surface scattering (if the surface scattering is assumed to be diffuse). Consequently, this film appears to be relatively pure.

Current pulses with a measured rise time of $\leq 2\times10^{-10}$ sec were generated by conventional coaxial line discharging techniques[12] employing a coaxial mercury relay. These current pulses passed through the thin film sample which was in the form of a hollow cylinder, 0.0283 inch in diameter and about 3/8 inch in length. The film sample constituted the end section of the outer conductor of the coaxial line in which the current pulse was generated. The center and outer conductors of this line were shorted together immediately beyond the film sample. A second coaxial line, concentric with the first and using the film sample as a portion of its center conductor, allowed the signal induced by a current pulse flowing through the resistive film sample to propagate out of the helium bath and into a sampling oscilloscope (response time $\leq 10^{-10}$ sec). This detection arrangement eliminates, at least, in principle, inductive coupling between the two coaxial lines and also can be built with a sufficiently wide-band frequency response to be commensurate with the sampling oscilloscope. An additional advantage of this arrangement is its

axial symmetry, resulting in uniformity of the current around the circumference of the hollow tin cylinder.

Typical results, as displayed by an X-Y recorder driven by the sampling oscilloscope, are shown in Fig. 1. Here the voltage drop along the tin film cylinder is plotted as a function of time, with current amplitude in amperes as a parameter. The vertical display system has been attenuated appropriately as the current was increased so that the display in Fig. 1 is actually the normalized resistance as a function of time. For the solid lines, the helium bath temperature was 3.2°K so that the film was initially superconducting. The dashed line represents the signal observed at 4.2°K, when the film was in the normal state at all times. The usual pulse repetition rate was 30 cps, but no changes were observed by going to 120 cps, demonstrating the absence of cumulative heating effects from one pulse to the next.

The solid-line wave forms in Fig. 1 show the appearance of resistance with increasing current pulse amplitude. The signal observed at 11.7 A does not appear to be associated with the thin film of tin. Its presence has been taken into account in the analysis of these data, although its origin and behavior are not completely understood. It is seen that the film can be made completely normal in a fraction of a nanosecond. A delay of about 1.5×10^{-10} sec is observed when the film is initially superconducting, but this delay corresponds to the time required for the current pulse to become large enough so that any portion of the film is resistive. These data demonstrate that the superconducting state can make the transition into the normal state completely in the order of 10^{-10} sec or less. This upper limit to the switching time does not differ substantially from previously reported results.[13-16] The important features of the present results are that the entire film is explicitly shown to be involved in the transition and that, as will now be shown, the minimum current required to induce the transition within the equipment response time is predictable from the superconducting properties of bulk tin.

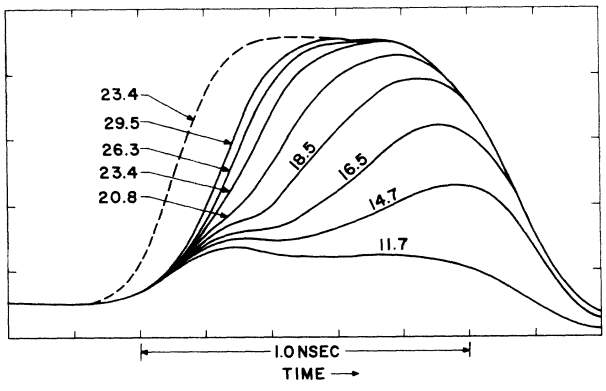

Fig. 1. The normalized resistance of the tin film as a function of time with measuring current in amperes as a parameter. The horizontal scale was 2×10^{-10} sec/div, and the residual film resistance was 0.0773 Ω. The dashed line represents the signal observed with the film initially in the normal state. The solid lines were obtained with the film initially at 3.20°K and superconducting. The duration and shape of the current pulse were the same for all pulse amplitudes.

When the film is initially in the normal state, the wave form requires about 2.5×10^{-10} sec to rise from 10% to 90% of its final value. The critical current for the superconducting state has been defined as the minimum current which produces 90% of the normal resistance at a time 2.5×10^{-10} sec after the current pulse achives 90% of its final value. Under this definition, the critical current in Fig. 1 is 23.4 A. Critical currents determined in this way are estimated to be ±6% in absolute magnitude but ±3% relative to one another.

In Fig. 2 we plot the measured critical currents as a function of the reduced bath temperature squared $(T/T_C)^2$. On this plot, the Silsbee hypothesis is a straight line, connecting 1.0 on the abscissa with 56 A on the ordinate. However, the measured values are expected to lie above this line becuase the film is temporarily cooled below the bath temperature by the latent heat of transition. The thermal conductance from the tin film into either the liquid helium or the glass substrate is limited to the order of 1 W/cm^2 °K by the acoustic mismatch[17] at the interfaces and appears to be small enough to isolate the film from its surroundings quite effectively for times as short as are of interest here. Consequently, until the film becomes normal and Joule heating commences, we assume that the transition may be treated as being adiabatic. In order to obtain the temperature of the normal film T_N immediately after the adiabatic transition from the superconducting state at bath temperature T, plots of the entropy of tin as a function of temperature for the superconducting and normal states were prepared.[18] The Silsbee current at T_N plotted at bath temperature T gives the solid line shown in Fig. 2 and is seen to be in reasonable agreement with the measured values over the

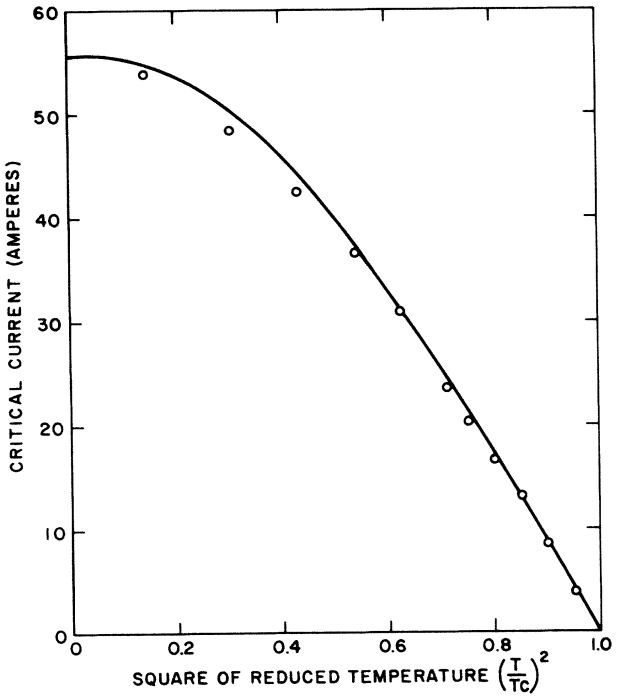

Fig. 2. The points are measured critical currents plotted as a function of the reduced bath temperature squared, while the solid line is obtained from the Silsbee value by assuming that the latent heat of transformation cools the film below the bath temperature. The film sample was cylindrical with a 0.0283-inch diameter.

entire temperature range.[19]

A detailed discussion of these results is not appropriate here. However, two additional observations will be made. In Fig. 1, it is seen that the rise times of the signals for 26.3 and 29.5 A at 3.2°K are practically the same as when the film was at 4.2°K and initially normal. If the switching time for the S→N transition is as short as 3×10^{-11} sec, as reported by Rose and Sherrill,[16] and if the detection system response time is shorter than 2.5×10^{-10} sec, one would expect to see a sharper pulse as a result of the S→N transition than with the film initially normal. The reason sharper pulses are not seen in Fig. 1 is probably high-frequency attenuation in the coaxial line coming out of the helium bath to the oscilloscope. However, the possibility that the S→N intrinsic switching time is of the order of 10^{-10} sec has not yet been completely excluded.

The other observation concerns the generation of Joule heat. It is seen in Fig. 1 that appreciable switching is taking place within 10^{-9} sec at currents distinctly below the Silsbee value. This switching is presumably a result of the thermal propagation of a large number of normal-phase regions. The details of this process are not understood. However, it seems possible, in view of the time scale involved, that the thermal transport process here may be wave propagation rather than diffusion, a mechanism recently discussed by Chester.[20] Further work is desirable in order to obtain an understanding of the growth of these normal regions, as well as their nucleation. In addition, extending the present type of measurements to substantially thinner films is of considerable interest in order to determine the effect of film thickness on the intrinsic critical current.

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ELASTIC-WAVE AMPLIFICATION IN YTTRIUM IRON GARNET AT MICROWAVE FREQUENCIES

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In this note we describe a series of experiments that have demonstrated parametric amplification of transverse and longitudinal elastic waves in ferrimagnetic garnets at microwave frequencies. The effects were observed at room temperature in single crystals of undoped and gallium-doped yttrium iron garnet (YIG) biased above magnetic saturation.

Parametric excitation of standing elastic-wave modes of ferrimagnetic garnet spheres has been observed,[1,2] and indirect observation of parametrically amplified traveling elastic waves in such materials has been reported,[3] but to our knowledge the experiments described in this note have provided the first direct observation of the amplification of elastic waves propagating in ferrimagnetic crystals. Two types of experiment are described. The first demonstrates parametric amplification of incoherent elastic waves present in the crystal as elastic-wave noise due to thermal agitation. The second demonstrates parametric amplification of coherent elastic waves injected into the crystal by an electromechanical transducer.

The essential details of our experiments are shown in Fig. 1. A single-crystal cylinder is located in a dc magnetic field with a small angle between the biasing field direction and the axis of the cylinder. An rf magnetic field may be applied to one end of the cylinder by means of a thin wire. A quartz plate is bonded to the other end. AC-cut plates were used to study transverse elastic waves, X-cut to study longitudinal waves.

Figure 2(a) shows a typical observation of the parametric amplification of elastic-wave noise. The lower trace shows the time during which a 1400-Mc/sec magnetic field was applied to an end face of a single-crystal cylinder of gallium-doped YIG ($4\pi Ms = 320$ G) 1.45 cm long and 0.43 cm in diameter. The upper trace shows a pulse of incoherent 700-Mc/sec elastic waves multiply reflected between the cylinder end faces. The delay time between pumping and first detection of the pulse shows that it originated at the wire end of the garnet cylinder.

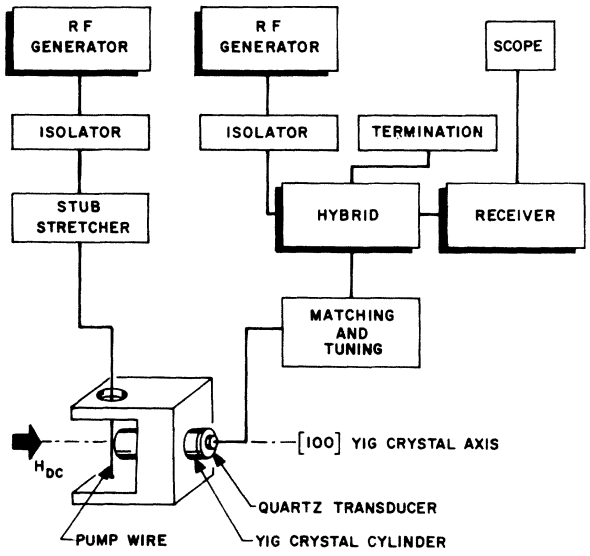

FIG. 1. Essential features of sample mounting and microwave circuitry used to observe parametric amplification of elastic waves.