

II. MICROWAVE SPECTROSCOPY*

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A. WORK COMPLETED

1. ELECTRICAL NOISE IN SUPERCONDUCTING FILMS

This research has been completed by J. M. Smith, and submitted to the Department of Physics, M. I. T., February 1972, in partial fulfillment of the requirements for the degree of Doctor of Philosophy. A summary of the thesis follows.

The noise properties of superconducting thin films in a perpendicular magnetic field have been investigated. Tin samples were used and the film thickness ranged from 1400 Å to 6500 Å. The observed noise level was larger than that expected on the basis of equilibrium temperature fluctuation noise, and the behavior of this excess noise was not consistent with properties of this mechanism. The excess electrical noise was observed only in the transition region, and only when the film was biased by a suitable current. The noise peaked in the lower part of the transition region, where the resistance of the film was small. Typically the maximum noise occurred when the resistance of the film was less than 1/10 of the normal value. A critical bias current density (J_0) was found to exist. No noise was observed at current levels less than J_0 . This critical current density was dependent on temperature and film thickness, and the increase of J_0 with increasing film thickness was significant. The noise power spectrum from 10 kHz to 200 kHz followed a $1/f^a$ dependence, where a was close to unity for the thick films (6500 Å) and slightly less than one for the thin films (1400 Å). A high-frequency tail with a more gradual falloff was observed at the higher frequencies (from 200 kHz to 50 MHz). The magnitude of the noise was striking. The noise power density at 10 kHz for a thick film (6500 Å) was equivalent to the power density from a 50 Ω resistor at several thousand degrees Kelvin. The noise decreased with decreasing film thickness.

The excess noise in zero field behaved differently from the magnetic field noise. At the same current level the zero-field noise was usually much larger. The noise spectrum fell off more slowly with frequency in zero field, and the noise peaked closer to

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the middle of the transition region ($R \approx .5R_N$).

The dominant source of noise was a flux-flow mechanism. The intermediate state of a superconducting film is usually unstable in the presence of a current. The magnetic flux domains are set into motion by the Lorentz force, and this motion produces voltage fluctuations (noise) in the film. The motion of the flux domains can also be detected by the induced EMF produced in a coil when it is placed close to the surface of a film.

Two other sources contributed to the noise. Bubbling in the liquid-helium bath produced temperature fluctuations in the film. These fluctuations were the dominant source of the low-frequency noise below 10 kHz. The equilibrium temperature fluctuations also created observable noise when high currents were applied. The magnitude of this noise, however, was very low.

In addition to the observed noise, coherent voltage pulses were generated by some of the superconducting thin films when these films were biased by a dc current source. These RF pulses occurred only in the transition region, and the fundamental frequency was found to be both current- and magnetic field-dependent. The frequencies involved were in the .1-30 MHz range. The exact origin of the pulses is unclear, but a flux-flow mechanism appears to be the source.

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