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Electrodynamics of Metallic Superconductors

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Abstract: The theoretical and experimental aspects of the microwave, terahertz, and infrared properties of superconductors are discussed.Electrodynamics can provide information about the superconducting condensate as well as about the quasiparticles. The aim is to understand the frequency dependence of the complex conductivity, the change with temperature and time, and its dependence on material parameters.

Key words: metallic superconductors,insulator,absorption,radiation

We confine ourselves to conventional metallic superconductors, in particular, Nb and related nitrides and review the seminal papers but also highlight latest developments and recent experimental achievements. The possibility to produce well-defined thin films of metallic superconductors that can be tuned in their properties allows the exploration of fundamental issues, such as the superconductor-insulator transition; furthermore it provides the basis for the development of novel and advanced applications, for instance, superconducting single-photon detectors.The absorption of electromagnetic radiation by a superconductor was directly investigated by measuring the temperature increase due to the deposited energy (bolometric absorption). A sputtered thin film of NbN on a silicon substrate (0.39mm) was mounted at the bottom of a highly reflecting copper light cone, supported by four strands of 25 μm diameter goldwire of about 1.5mmlong.This gives the bolometer a thermal response time constant of about 30ms at 10.8 K. The temperature is measured by a small doped silicon thermometer glued to the back of the silicon substrate. The resistance of this thermometer is exponentially decreasing with increasing temperature

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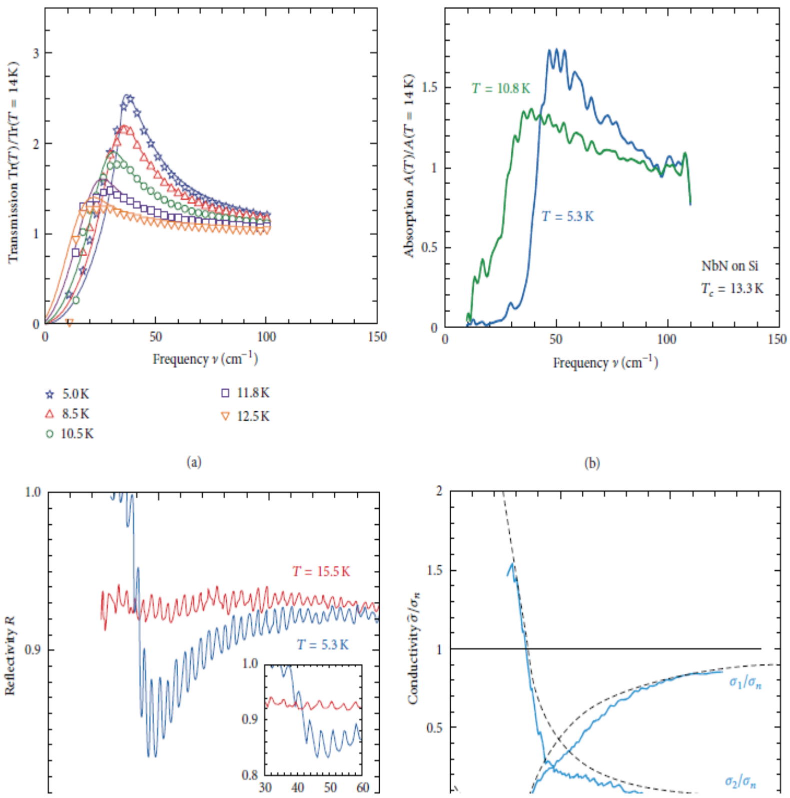
[85]. In Figure 10(b) the relative power absorption spectra are plotted for a 250 nmNbN superconducting film (T= 13.3 K) on a 0.39mm silicon substrate. The curves are taken at 5.3 K and 10.8 K and each normalized to a normal state spectrum taken at T = 14K. With decreasing frequency, the absorption increases and exhibits a maximum around the superconducting energy gap, before it rapidly drops to zero; the behavior is more pronounced for lower temperatures. Pic{1}shows the reflectivity of theNbNfilm on Si substrate above and below Tc. The reflectivity in the normal state is relatively low (due to the particular film thickness), makingthe superconductivity behavior very evident. While in the normal state at 15.5K the reflectivity levels off around R ≈0.93, a pronounced dip is observed in the superconductingstate before the reflectivity rapidly rises to 1.0 Ѓ} 0.01 for frequencies below 40 cm−1, clearly indicating the superconducting gap frequency. In any case the high-resolution reflection spectra exhibit pronounced interference fringes due to multireflection within the Si substrate. In particular, one can see in the inset that the phase of the fringes at 5.3K



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The nature of the superconductor-insulator transition and especially that of the insulating phase is still underdebate. Recently several indications for the presence of and a number of possible explanations have been put forward. One suggestion relates the phenomena to the inhomogeneous nature of the system under study [134, 135]; near the superconductor-insulator transition on both sides.

Advances in Condensed Matter Physics 21 of the transition the system is composed of regions of superconductingmaterial embedded in an insulatingmatrix.

In this picture, the transition occurs when the isolated superconducting islands are able to Josephson-couple and allow the many-body wave function to percolate throughout the entire system. There are basic arguments [136, 137]

and theoretical considerations [138, 139] that actually anticipate that inherent inhomogeneity has to occur near the -insulator transition even when the system

is structurally uniform and compatible with the underlying disorder (which, near the SIT of a typical superconductor, is fairly strong). Therefore, some inhomogeneity is expected to be present near the superconductor-insulator transition in all systems where the transition temperature does not drop to zero before a substantial disorder has set in (which in 2D is equivalent to the SIT occurring when the sheet resistance R is of the order of the quantum resistance There are quite a few systems that seem to exhibit transport properties that are consistent with this expectation. An example is the situation in amorphous InO films, one of the systems that showed the peculiar features alluded above.

Structural study reveals morphological inhomogeneities on scales of order 100 ˚ A. Transport studies, however, exposed scale dependences up to few microns [136, 137]. Another candidate is films of NbN that exhibit higher Tc and thus are suitable for optical experiments in the THz range. A second picture invokes the existence of uncorrelated preformed electron pairs which do not constitute a condensate but are characterized by an energy gap that is associated with the pair binding energy. Other models adapt concepts from both pictures [142] and suggest that above Tc and on the insulating site the filmis composed of small superconducting islands that are uncorrelated and are too small to sustain bulk superconductivity. Hence, the situation is unclear, and further experimental information is required.

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