Goodman *et al.*[10] present evidence indicating that, at the level of the light microscope, the distribution of spectrin and 4.1 (as detected by an antibody to erythrocyte 4.1) in the cerebellum are identical and extend to neuroglia as well as neurones. The latter contrasts with the virtually exclusive localization of synapsin I in the nerve terminal[1]. These results cannot be explained purely on the basis of the very high concentration of synapsin I in the nerve terminal (where it constitutes about 6 per cent of the vesicle protein), because immunocytochemistry using anti-synapsin immunoglobulin confirms the restricted location. Therefore, it seems likely that synapsin I is a highly specialized form of 4.1 found only in neurones. This conclusion confirms the overwhelming impression that synapsin I must play a unique role in some aspect of synaptic transmission. □

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Solid-state physics

How superconductivity fades near metal–insulator transitions

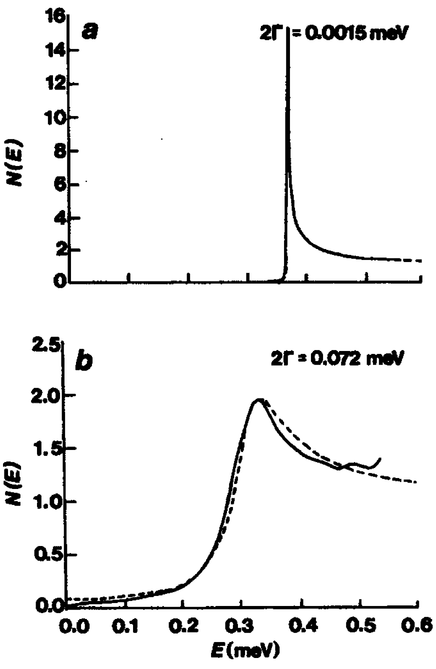
from W.L. McLean

ALTHOUGH the importance of quantum mechanics in solid-state physics has been well established for many decades, it came as a rude surprise about five years ago that startling quantum effects in metallic conduction had been overlooked. Unusual behaviour and bizarre predictions near the metal-insulator transition have recently come to be expected. Further challenging questions arise when the system can also be superconducting. One of these that is less innocent than it first seems is whether superconductivity can persist into the insulating side of the transition. If not, does it die out right at the transition or while the system is clearly still on the metallic side? R.C. Dynes, J.P. Garno, G.B. Hertel and T.P. Orlando have recently shed new light on this area by measuring electron tunnelling in the granular aluminium system (*Phys. Rev. Lett.* **53**, 2437; 1984).

Granular aluminium, which is a mixture of grains of metallic aluminium and amorphous aluminium oxide, is one of a number of systems from which a series of specimens, ranging from pure metallic to pure insulating, can be prepared by varying the metal volume fraction. The granularity, which can be seen by transmission electron microscopy, is clearly marked in the middle range of concentrations, where the metal-insulator transition occurs. Many theoretical models that attempt to explain properties of granular metals do explicitly take this granularity into account.

A very different interpretation that has been used by Dynes *et al.*, among others, is that the properties of granular aluminium can be interpreted as if the system were an amorphous metal in which the disorder is on an atomic scale. This outlook is commonly justified by the assumption that all relevant length scales are larger than the grain size, and it is in this framework that the importance of the new tunnelling measurements becomes apparent.

The experiments use the technique of electron tunnelling at low temperatures of approximately 0.06 K, which is much less than the superconducting transition temperature, to measure the density of states of the elementary excitations (quasiparticles) of the superconductor. In low resistivity specimens it is not surprising that granular aluminium behaves exactly as an ordinary superconductor with a sharp asymmetrical peak in the density of states clearly defining the edge of an energy gap, in good agreement with the Bardeen, Cooper, Schrieffer (BCS) theory of superconductivity. At higher resistivities very close to the metal-insulator transition, however, the density of states is no longer zero at low excitation energies and the discontinuity is replaced by a broad smooth maximum.



The density of states, $N(E)$ deconvoluted from the experimental data. The dashed line is a BCS density of states broadened by the value of Γ shown in each figure. The 'lifetime' of a quasi-particle is $\hbar / \Gamma$. *a*, Specimen with small broadened effects; *b*, specimen very close to metal-insulator transition (modified from Dynes, R.C. *et al. Phys. Rev. Lett.* **53**, 2437; 1984).

Dynes *et al.* have successfully fitted their data with a BCS density of states modified to take into account broadening caused by a finite lifetime of the quasi-particles in the granular superconductor. In this case the lifetime is limited by inelastic scattering processes, which have been of great interest recently in connection with the tendency of electron states to become localized as the metal-insulator transition is approached. The values of the inelastic scattering rates deduced from the tunnelling measurements are consistent with those deduced from a different experimental approach, measurement of the magnetoresistance.

Thus, superconductivity seems to die away near the metal-insulator transition by a gradual lifetime broadening of the density of states concomitant with the appearance of quasi-particle states in the region where there is an energy-gap in lower resistivity specimens. A particular oddity of these results is that they imply that moderately strong indications of superconductivity still appear close to the energy at which the sharp peak occurred in the low resistivity specimens. This may be connected with the long tails reported by Dynes *et al.* in the resistive transitions of the highest resistivity specimens.

Further intriguing questions are: first, what happens at much lower temperatures when the lifetimes of the quasi-particles should become longer? Does the full BCS gap reappear? The implication is that the closer one approaches the metal-insulator transition, the lower must the temperature be in order to see the full superconductivity. Second, does some inelastic scattering mechanism peculiar to the granular structure come into play or are the mechanisms found in amorphous metals still operating in the granular system?

Although the new results seem to provide firm support for the quasi-homogeneous medium approach, it still remains to reconcile this point of view with approaches that do assume the granularity to be relevant. These include those workers who seek to explain the properties of granular metals in terms of percolation through an assembly of randomly linked grains, and those focusing on the consequences of electrostatic charging of the grains on the stability of the superconductivity. □

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