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EFFECT OF THE TEMPERATURE AND THE MAGNETIC FIELD ON THE
CAPACITY OF Al-Sn AND Al-In TUNNELING JUNCTIONS

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Measurements showing an increase of capacity of Al-Sn and Al-In. In superconducting tunneling junctions as the temperature is decreased are reported. The effect of the magnetic field on the capacity has been also observed. Possible explanations are suggested.

We report a series of capacity measurements carried out on a number of Al-Sn and Al-In tunneling junctions which clearly show that the capacity of these junctions increases when one of the metals (Sn or In) goes into the superconducting state.

The junction preparation technique is the usual one which has been employed in many other tunneling experiments. For the capacity measurements we have employed a bridge circuit, with a lock-in amplifier as zero detector. We carried out our measurements by the substitution method. The junction values R_g and C_g are related to the substitution values R_S and C_S and the analysis of the equivalent circuit of the tunneling junction gives to a good approximation:

$$R_S = R_1 + R_g, \quad C_S = (R_g/R_S)^2 C_g$$

where R_1 is the electrical resistance of the aluminum film, measured independently. The capacity measurements have been performed with zero d.c. polarization voltage so that the parameters which determine R_g are the temperature T and the applied magnetic field H parallel to the junction plane. Two different working frequencies have been used, 5 kc/s, and 10 kc/s but we

Table 1

Specimen No.	Type of junctions	δ (Å)
1	Al-Sn	1.5
2	Al-Sn	1.4
3	Al-Sn	1.6
4	Al-In	1.2
5	Al-In	1.2
6	Al-In	1.1

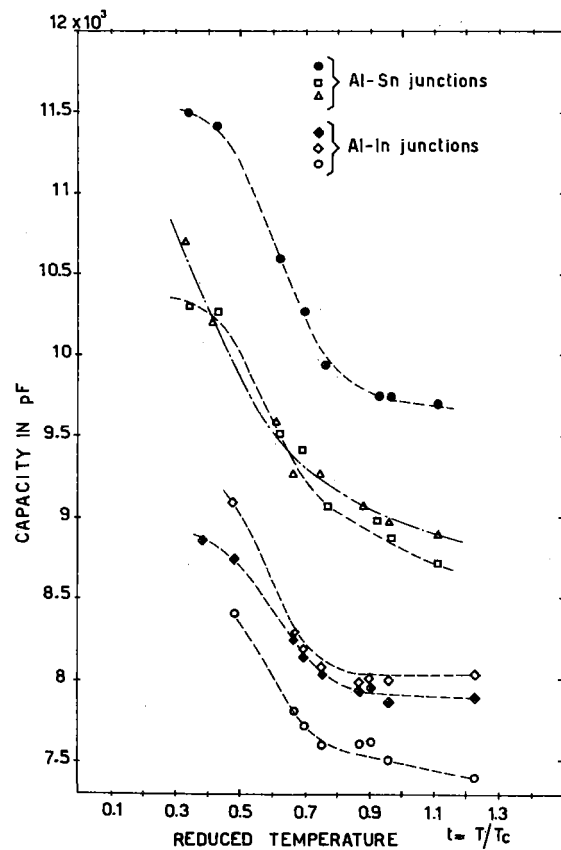


Fig. 1. The capacity of the tunneling junctions versus reduced temperature.

have not found significant differences in the experimental results.

Fig. 1 shows the capacity of different junctions as a function of the temperature T in zero external magnetic field while fig. 2 shows the capacity as a function of the applied magnetic

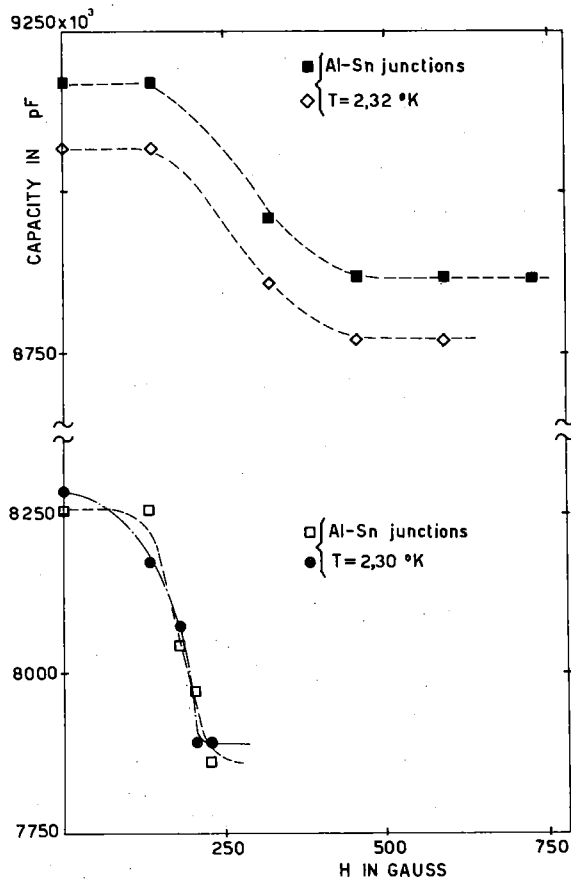


Fig.2. The capacity of the tunneling junctions versus applied magnetic field.

field, the temperature being constant. The precision of capacity measurements is ± 30 pF while the temperature is stabilized up to 0.01°K . For a sufficiently strong* magnetic field, the measured resistances and capacities were equal to the values obtained at 4.2°K . In table 1 are reported the values of the difference δ (in \AA) between the values of d ($d = \epsilon_0 S/C$ where S is the junction sur-

* That is at field values for which the tunneling curves exhibit a linear behaviour corresponding to the fact that at least in the junction zone the superconducting metal goes into the normal state.

face whose value is about 1 mm^2) at 4.2°K and at $\sim 1.3^\circ\text{K}$ for different specimens. Analogous measurements carried out on several Al-Ag junctions have shown no variation of the capacity of this system with the temperature. This fact put in evidence that the increase of the capacity is due essentially to the presence of a metal which undergoes the superconducting transition.

It is easy to see that the capacity of a tunneling junction can be represented to a first approximation by the formula:

$$C_g = \frac{\epsilon_0 S}{\lambda' + \lambda'' + (t/\epsilon_r)}, \quad (1)$$

where λ' and λ'' are the electric field penetration depths in the aluminum and in the superconducting metal respectively. ϵ_r and t are the relative dielectric constant and the effective thickness of the insulator. The capacity variation may be ascribed to a variation either of λ'' or of effective insulating thickness t . In the normal metals the calculated value of λ'' [1-3] is about $1-2 \text{\AA}$, i.e. of the order of magnitude of the measured δ (see table 1). On this hypothesis in superconductors like tin or indium the screening action seems to become much more effective than in a normal metal.

On the other hand variations of the effective insulating thickness t can be ascribed to the superelectron wave function penetration in the insulating layer itself [4]. Further work is in progress in particular to determine more accurately the temperature dependence law of the capacity.

References

1. S.Raimes, The wave mechanics of electrons in metals (North-Holland Publishing Co., Amsterdam, 1961) p.281.
2. J.M.Ziman, Electrons and phonons (Clarendon Press, Oxford, 1960) p.159.
3. R.Brout and P.Carruthers, Lectures on the many-electron problem (Interscience Publishers, New York, 1963) p.100.
4. W.A.Little, private communication.
