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Electronic Resonance in Current-Carrying Solutions

A. A. GALKIN, IA. L. SHAMFAROV
AND A. V. STEFANISHINA
Institute of Radiophysics and Electronics, Academy of Sciences, U.S.S.R.

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AS IS KNOWN, electronic resonance is observed in ammonia solutions of alkali metals.[1,2] This effect is due to the fact that in ammonia solutions the atoms of the alkali metals dissociate into electrons and positive ions. The positive ions have a noble gas electron structure and are diamagnetic, while the electrons, having a magnetic moment, are responsible for the electron resonance effect.

It must be noted that solutions of alkali metals in liquid ammonia are colored, the coloring being explained by the presence of "free" electrons in the solution.[3]

It was shown by Gordon and Broude[4] that coloring is observed in an initially colorless solution of table salt in ammonia when a current is passed through the solution. The developing color is reminiscent of that characteristic of ammonia solutions of alkali metals. These investigators also noted the deflection of the colored streams in a magnetic field, which, according to these authors, is indicative of the electronic character of the conduction.

We felt that deflection of streamlines in a magnetic field is not in itself a convincing argument in favor of electron conduction. Hence we undertook a series of experiments on detection of electronic resonance in solutions of NaCl in ammonia on the assumption that in the case of electronic conduction, electronic resonance incident to the passage of current should be observed. Obviously, the electronic resonance line in this case should have a shape and spectroscopic splitting factor analogous to those of the line observed in solutions of Na in NH_3.

For observation of electronic resonance at a frequency of 9000 Mc the ampoule containing the ammonia solution of NaCl was placed in the rectangular cavity (H_{102} mode) of a sensitive radiospectrometer. The ampoule had two sealed-in platinum electrodes.

As usual the cavity was placed in a constant magnetic field, modulated by a field having a frequency of 50 cps. The intensity of the constant field was selected so as to satisfy the condition $g\mu H = h\nu$, where g is the radio-spectroscopic splitting factor for the solution, μ is the magnetic moment of the electron and ν is the frequency of the radiospectrometer generator. The investigation showed that under ordinary conditions no electronic resonance is observed when there is no current through the salt solution. When a current is passed through the solution an electronic resonance line appears at approximately the same place as the line associated with Na in liquid NH_3 (see Fig. 1). The intensity of the line depends on the strength of the current. When the current is switched off the intensity of the absorption line gradually decreases.

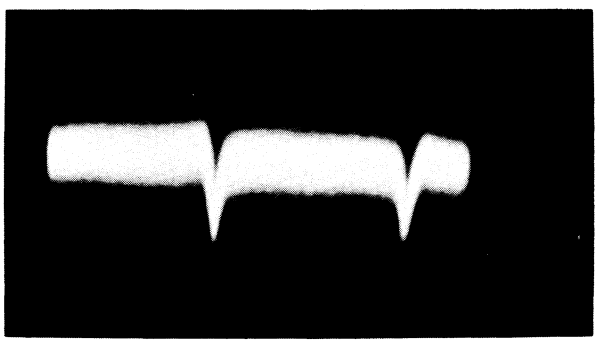

FIG. 1. Oscillogram of electronic resonance of a solution during passage of current.

Thus it is possible to observe electronic resonance only when electrons associated with the passage of current through the solution are present; this substantiates the electronic character of the conduction in these solutions.

If at the time of passage of current through the ampoule the solution is frozen in liquid nitrogen, the color of the solution is retained (there is no recombination of the electrons with the chlorine) and it is possible to observe electronic resonance even in the absence of a current (Fig. 2). In this manner

it is possible to produce a medium with an easily controlled number of free electrons.

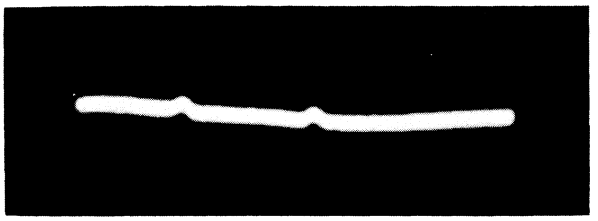

FIG. 2. Oscillogram of electronic resonance of a frozen solution.

The concentration of electrons can readily be determined from the intensity of the electronic resonance line.

We believe that the electronic resonance method described above may prove useful in determining the nature of different solutions.

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Discontinuous Attenuation of Current In a Superconducting Ring

A. A. GALKIN, IA. S. KAN AND B.G. LAZAREV
Physico-Technical Institute, Academy of Sciences, Ukrainian SSR

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IN AN EARLIER INVESTIGATION, devoted to the kinetics of the transition from the normal state to the superconducting one, it was shown that the resistance of the specimen is a non-monotonic function of the temperature and fluctuates between zero and the normal value as the temperature is gradually decreased.[1,2] These fluctuations of resistance were related, in particular, with the kinetics of formation of an intermediate state arising in the process of destruction of the superconductivity by the current. It was assumed that an analogous but reverse effect might be observed during transition of a superconducting ring in which a current was induced to the normal state, *i.e.*, that the current would attenuate in jumps with gradually increasing temperature.

The experiments described herein were set up for the purpose of investigating the process. The apparatus consisted of a 10 mm radius lead ring made of 1 mm diameter wire and a coil of 8000 turns of copper wire mounted coaxially with the ring. By means of this coil it was possible to measure both the full current in the ring (by turning the coil about an axis in the plane of the ring) and the change in current ΔI (from the change in the induced emf produced by ΔI). In the first case the coil was connected to a ballistic galvanometer, in the second to a short-period galvanometer.

The coil and ring were enclosed in a copper cup immersed in liquid helium. By filling the cup with gaseous helium at a pressure of 1–2 mm Hg, the system could be cooled to the temperature of the helium bath. By applying a magnetic field $H > H_k$ and then cutting it off, a current $I = I_k$ was induced in the ring. After this the helium was pumped out of the cup to a residual pressure of $10^{-6} - 10^{-7}$ mm Hg and the ring slowly and gradually warmed. The rate of heating could be regulated and in most cases was $10^{-4} - 10^{-5}$ degrees/sec.

Part of the curve characterizing the variation with time of the emf in the measurement coil while the ring with the initially induced current was heated is shown in the accompanying figure. It will be seen that the current in the ring does not attenuate gradually, but falls off in jumps of several seconds duration; in the intervals between jumps the emf equals zero, *i.e.*, the current does not change during the interval.

From the $E(t)$ curves one can determine the relative change in current $\Delta I/I$ occurring during each jump. In the vicinity of 4.2° K the average value of $\Delta I/I$ for the lead ring is 10^{-4}.

Knowing $\Delta I/I$, the self-inductance of the ring, $L \approx 40$ cm, and the current attenuation time τ, one can evaluate the effective resistance responsible for the damping:

$$R_{\text{eff}} = (\Delta I/I)\, L/\tau \approx 10^{-11} \text{ ohm}.$$

Inasmuch as the total resistance of the ring in the normal state was $\sim 10^{-7}$ ohm, we can say that, re-