

An Attempt to Detect the Raman Effect in a Superconductor

M. S. KHAIKIN AND V. P. BYKOV
Institute for Physical Problems
Academy of Sciences, USSR

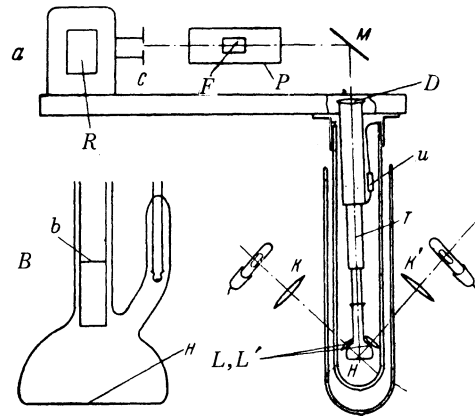
(Submitted to JETP editor July, 26, 1955)
J. Exper. Theoret. Phys. USSR **30**, 191-192
(January, 1956)

THEORETICAL considerations¹ indicate that it is possible that a gap of width $\Delta \sim kT_k$ appears in the electronic energy spectrum of a metal when it goes over into the superconducting state (T_k = transition temperature). Thus, when a light quantum ($h\nu > \Delta$) interacts with a metallic electron, Raman scattering of the light ought to take place, with a change of wavelength $\Delta\lambda = \lambda_0^2 \Delta / ch$; or, since $\Delta \sim kT_k$, $\Delta\lambda \approx (k/ch) \lambda_0^2 T_k \approx 0.7 \lambda_0^2 T_k$, cm. For the D line of sodium this quantity amounts to $\sim 2\text{\AA}$ for scattering from lead ($T_k = 7.2^\circ\text{K}$). The intensity of the light scattered in this way should, apparently, be very small.^{2,3,4,5}

The first attempt to observe the Raman effect in a superconductor was made by Verkin and Lazarev⁶ but since their observations were carried out in reflected, rather than scattered light, they could observe only an extremely intense satellite. In the present work we undertook an investigation of the spectrum of scattered light, insuring the possibility of detecting extremely weak satellites.

When light of constant frequency is scattered by the inhomogeneities of a reflecting surface, a background is produced in the region of a satellite (because of the non-ideal monochromaticity of the light source) which limits the possibility of observing Raman scattering. A calculation shows that for our light source (see below) the radiation intensity in the region of the Raman satellite amounts to less than $10^{-3} - 10^{-4}$ of that at the center of the line. Since the surface of the sample scatters only a small fraction ($\sim 10^{-6}$)⁷ of the light which would be scattered by a mat white surface, the background in the region of the Raman satellite amounts to $10^{-9} - 10^{-10}$ of the intensity at the center of the line of the incident light. This consideration sets a theoretical lower limit to the intensity of the Raman-scattered light which we could detect.

We used an autocollimated spectrograph with an echelette-type diffraction grating, having the following characteristics: a resolving power of 10^5 in the region of the D doublet, linear dispersion of $4\text{\AA}/\text{mm}$ in the same range, a luminosity of 0.0015, and a focal



length of 2 m. The grating was cut on aluminized glass and had 51,000 lines (600/mm). Approximately 50% of the light incident on the grating was concentrated into the first and second orders. The presence of weak ghosts, 4.5 \AA distant from the line, could not interfere with our observations.

It was necessary to look in the spectrum for the hypothesized satellite at a distance of 0.2-0.5 mm from the center of the line. In order to prevent the formation of a corona, a resonant filter (see F in Fig. a) was placed along the path of the scattered light, which weakened the light of the original frequency by a factor of about 1000. The filter was made from pyrex in the form of a tray with plane-parallel top and bottom, and contained a small quantity of sodium and neon at a pressure of 1.7 mm (at 20°C). During an experiment the filter was heated to $255 \pm 5^\circ\text{C}$. The pressure of the neon and the temperature of the filter were selected so that there was no appreciable absorption at a distance of 0.5 \AA from the center of the line.

The samples were made from lead whose impurity content did not exceed 0.05%. Since the most important requirement for a sample was that it have a good reflecting surface, we used thin (10^{-5} cm) lead films, prepared by Shal'nikov's method⁸: the metal was evaporated in a vacuum onto a glass backing cooled to helium temperatures. The backing we employed was the smooth concave surface of a piece of glassware (Fig. b). Since at the temperature of liquid helium boiling under normal pressure (4.2°K) lead has already gone over into the superconducting state, the experiments were also carried out at this temperature.

Two spectral sodium lamps were used as light sources. With the aid of the condensing lenses K, K', L, L' (see figure), light from these lamps was directed onto the superconducting film H , applied on the inner surface of the small flask. A magnified image B (Fig. b) of the blackened inner

surface of the deposited lead was formed in the concave lead mirror, so that the scattered light was observed as though it had an "absolutely black" body for its background. With the aid of the lens *D* and the pivoted mirror *M*, the image of the sample was projected on the slit of the spectrograph *C*, so that the scattered light passed through the resonant filter *F*, located in the furnace *P*. In order to prevent fogging of the flask from the freezing-out of air when the apparatus was cooled with liquid helium, the interior of the tube *T* was evacuated to a pressure of $\sim 10^{-3}$ mm Hg, and the remaining gas adsorbed by cold activated charcoal *u*. The spectrum of the light scattered by the sample was observed visually and also registered photographically on RF-3 X-ray film, which had been shown to be the most sensitive for the *D*-line.

Three experiments were carried out with exposures of 4, 11, and 12 hours. In visual examination of the scattered light, or in these photographs, no satellites were observed in the region of the *D*-doublet. Comparison of the exposures used in this experiment with those required in order to obtain noticeable blackening from light of intensity I_0 scattered by a mat white surface shows that a satellite of intensity $\sim 10^{-7} I_0$ could have been detected.

The authors express their profound gratitude to Professor A. I. Shal'nikov for his interest in this research.

¹ V. L. Ginsburg, *Usp. Fiz. Nauk* **48**, 25 (1952).

² E. Hirschlaff, *Proc. Camb. Phil. Soc.* **33**, 140 (1937).

³ J. G. Daunt, T. C. Keely and K. Mendelsohn, *Phil. Mag.* **23**, 264 (1937).

⁴ R. Hilsch, *Phys. Z.* **40**, 592 (1939).

⁵ K. G. Ramanathan, *Proc. Phys. Soc. (London)* **A65**, 532 (1952).

⁶ B. I. Verkin and B. G. Lazarev, *Izv. Akad. Nauk SSSR Ser. Fiz.* **12**, 598 (1948).

⁷ C. V. Raman and L. A. Ramdas, *Proc. Roy. Soc. (London)* **A108**, 561 (1925).

⁸ A. I. Shal'nikov, *J. Exper. Theoret. Phys. USSR* **10**, 636 (1940).

Translated by W. M. Whitney

26

Glow of Aluminum Alloys in an Electrolytic Bath

V. A. KRASNOKUTSKII

Khbarovsk

(Submitted to JETP editor July 24, 1955)

J. Exper. Theoret. Phys. USSR **30**, 192-193
(January, 1956)

IT is well known that aluminum and its alloys have protective oxide coatings on their surface,

which prevent the penetration of oxygen into the interior of the metal. Much research¹⁻⁴ has been devoted to studies of the structure and properties of such oxide layers, in which the physical-chemical properties of the anticorrosive layers on aluminum have been studied rather thoroughly.

This paper presents a series of qualitative observations which reveal yet another feature, associated with the production of oxide films and their structure, namely the ability of aluminum and its alloys to glow under the action of an electric current in solutions of certain salts and bases.

The experimental arrangement for observation of the phenomenon of the glowing of electrodes in solutions of electrolytes during the passage of an electric current consisted of a bath containing the electrolyte and the electrodes. Alternating current was supplied from the line at 220v and direct current was supplied by a vacuum tube rectifier. Samples in the form of plates 50 mm \times 30 mm \times 1 mm and 60 mm \times 70 mm \times 1 mm were used as electrodes. The following materials were tested: copper, bronze, brass, lead, zinc, iron, silver, aluminum and its alloys AM, AMZ, D-1, D-16, "electron", "silumin" and others.

The following materials were used as electrolytes: 1-10% solutions of the salts: NaCl, NaBr, KCl, NaHCO₃, Na₂CO₃, NH₄Cl, MgSO₄, (NH₄)₂SO₄, Na₂SO₄, K₂SO₄, KAl(SO₄)₂, Na₂HPO₄, Na₃PO₄, CaHPO₄ and also 0.1-5% solutions of the bases NaOH, KOH and others.

During the observations, the potential drop between the terminals of the bath was read to an accuracy of 1v, while readings of the bath temperature were correct to 1°.

When the current flows through the bath in the dark, a uniform glow of the whole surface of the electrode can be observed by the unaided eye which in a way reminds one of the glow of luminescent material. In a 5% solution of NaHCO₃ the onset of the glow occurs at a voltage between 20 and 25v, and with increasing voltage, its intensity correspondingly increases.

By trying a number of different metals and alloys it was noticed that the glow occurs only on aluminum and its alloys. It was characteristic of these, that the color of the radiation of each aluminum alloy remains unchanged independent of the composition of the electrolyte, provided that, in the given electrolyte, the glowing does occur. Thus, for example, pure Al has a pale blue, nearly white radiation; the alloy AMZ has a rather intense orange colored radiation. It is difficult to distinguish visually the characteristics of the glow of the alloy D-1 from the glow of the alloy D-16,