The paper "Magnetic-flux quantization in a cylindrical film of a normal metal"D.Yu. Sharvin and Yu.V. Shashkin (1981)

The paper [1] is one of the last papers from the time of romantic physics. To have success in experimental investigations at that time, it was necessary to reasonably formulate the aims of the experiment, to be able to use appropriate experimental techniques, and to prepare the object of investigations by one's own hands without using high technology methods.

The goal of the experiments by D.Yu. Sharvin and Yu.V. Sharvin was to verify the theoretical prediction made by B.L. Alt'shuler, A.G. Aronov and B.Z. Spivak [2] who calculated the contribution of electron wave function interference to the charge transport at low temperatures.

Let us consider an insulating cylinder coated by a thin film of a normal metal. The probability amplitude for the electron to return to some point on the film can be presented as the sum of amplitudes for all diffusive trajectories starting and finishing at this point. Such trajectories include pairs with scattering processes that occur on the same impurities but in the opposite sequence. The change of the phase of the electron wave function is the same for each trajectory of the pair. Therefore, at the final point for the pair the moduli of the probability amplitudes should be summed up, in contrast to summing probabilities for the other trajectories. Thus, the existence of pairs increases the probability of electron return to the starting point, which leads to an increase of the electric resistance of the film.

In a magnetic field directed along the cylinder axis the electron wave function acquires an additional phase, proportional to the magnetic flux through the closed trajectory. The additional phases for the pairs' trajectories have opposite signs. The phase difference is equal to 2π multiplied by integer n if the magnetic flux through the cylinder cross section is equal to $\phi_0 = nhc/2e$. So, quantum oscillations appear in magnetic fields with a period that is not typical of normal metals. To observe these oscillations, it is necessary to have the cylinder diameter much smaller than the electron dephasing length, e.g., due to phonon scattering.

First of all, the authors of the paper made an insulating cylinder with diameter about one micrometer in which case the electrons in the metallic film at helium temperatures keep the phase memory along trajectories surrounding the cylinder. They used a crossbow whose arrow pulled after shot a thin filament from a piece of molten quartz. The search for parts of the filament after shot was not easy.

Magnesium was chosen as a normal metal because it was known that Mg films are in the normal state, at least, at temperatures above 50 mK. It was very important to have the film in the normal state in the experiment since the quantum oscillations with magnetic flux change corresponding to the double electron charge (the charge of the Cooper pair) are typical of superconductors.

Films were prepared by evaporation of magnesium in a cooled with liquid nitrogen vacuum chamber that was filled with a small amount of pure helium at a pressure of 10^{-3} mm Hg. Two films with length 1 cm were used for two-terminal measurements of resistance in weak magnetic fields. The diameter of one of the films, equal to 1.58μm, was measured using an electron microscope. Resistance oscillations were found in magnetic fields $H \leq 50$ Oe in both films. It was shown that the oscillation period corresponds to the double electron charge.

The experimental work [1] generated the big number of publications dealing with the Aharonov-Bohm effect in metallic films and two-dimensional electron systems. The objects for investigations were prepared using modern methods, e.g., electron beam lithography.

[1] D. Yu. Sharvin and Yu. V. Sharvin Письма в ЖЭТФ 34, 285 (1981).

[2] B.L.Alt'shuler, A.G. Aronov, B.Z. Spivak Письма в ЖЭТФ 33, 101 (1981).