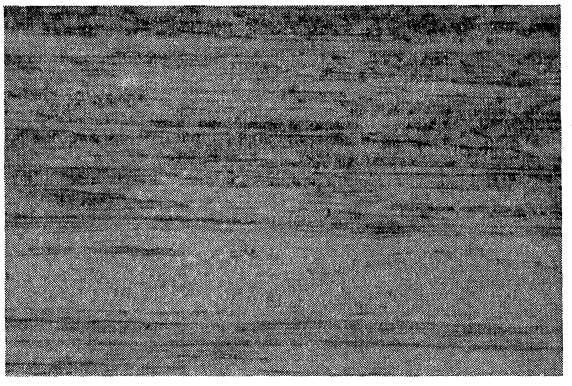
TABLE I. Resistivities, electronic mean free paths (l), and grain diameter (d).

Sample	Temp. of anneal, °C	4.2°K Ωcm×10⁸	l cm×10³	d cm×10³
	Present data			
0−A	C.W.[a](new)	4.88	0.13	···
	C.W.(old)	4.18	0.16	···
	~500(old)	0.34	1.9	0.9
0−B	C.W.	5.09	0.13	···
	~200	1.18	0.55	···
	~350	0.81	0.81	0.9
	Blewitt *et al.*			
305D	C.W.	1.31	0.50	···
	~1000	0.91	0.72	10²

[a] C.W. = cold-worked.

annealed in high vacuum at approximately 500°K it does not show a larger ρ_{anom} than do the highly cold-worked samples. Figure 2 shows the microstructure of the sample in the highly cold-worked and annealed states. It is clear that the number and arrangement of grain boundaries has changed markedly during annealing. The results on sample 0−B also confirm that changes in grain structure play no detectable role in determining the magnitude of the resistance minimum,



(a)

(b)

FIG. 2. Microstructure of cold-worked and annealed samples 0−A. ×500. (a) Cold-worked; (b) annealed.

for here again there is no apparent change in ρ_{anom} between the cold-drawn wire and the annealed wires. In Table I are compiled the resistivities and electronic mean free paths, l, of our samples at helium temperature along with an approximate grain diameter, d, for some of the annealed samples. The grain diameters are of the same order of magnitude as the computed free paths, indicating that a considerable fraction of the residual resistivity likely arises from grain-boundary scattering in these cases.

Blewitt and co-workers' results on a worked single crystal and on the same sample after recrystallization are given in Fig. 1 and Table I. The mean free path in Blewitt's recrystallized samples is a small fraction of the grain size[4] of these samples.[5] Thus, grain-boundary scattering must contribute very little to the total residual resistivity of these samples—in contrast with the case of our recrystallized samples. It is possible, then, that the resistance minimum observed by Blewitt may arise from additional scattering centers present within the grains of his samples.

Koehler[4] points out that using the grain size of Blewitt's samples as a mean free path gives a computed resistivity roughly equal to only ρ_{anom} extrapolated to 0°K. This correspondence he takes as confirmation of the hypothesis that the resistance minimum may be the result of grain-boundary scattering. However, a similar argument with respect to our samples would lead one to expect ρ_{anom} in the annealed samples at 0°K to be of the same order of magnitude as the residual resistivity itself. This result is incorrect by about two orders of magnitude.

[1] Blewitt, Coltman, and Redman, Phys. Rev. **93**, 891 (1954).
[2] Smith, Smart, and Phillips, Trans. Am. Soc. Mech. Engrs. **143**, 272 (1941).
[3] D. K. C. MacDonald, Proceedings of the Schenectady Cryogenics Conference, October, 1952, p. 154.
[4] J. S. Koehler, Phys. Rev. **94**, 1071 (1954).
[5] M. H. Cohen and C. S. Barrett, Phys. Rev. **95**, 1094 (1954).

Electrical Resistivity Minimum Reported in Copper-Zinc Alloys

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GERRITSEN and Linde[1] report that the addition of small amounts of zinc to copper gives rise to a resistance minimum. Experiments done at this Laboratory do not confirm this result, and we have found no resistance minimum in these low-percentage alloys that can be ascribed to the zinc. Our results are illustrated and compared with those of Gerritsen and Linde in Fig. 1, where $\rho_{\text{anom}} \equiv \rho_T - \rho_{4.2°\text{K}}$ is plotted *vs* temperature in the liquid helium temperature region. The curves attributed to Gerritsen and Linde are computations

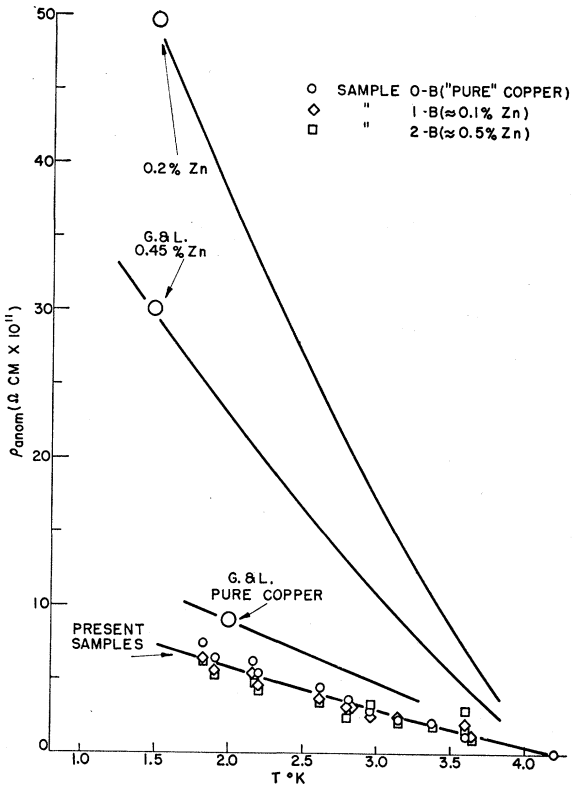

FIG. 1. $\rho_{\text{anom}} \equiv \rho_T - \rho_{4.2°K}$ *vs* temperature for copper-zinc alloys.

from their smoothed curves of resistance ratio *vs* temperature for their alloys. Our samples, which were prepared by melting the components in sealed-off, evacuated quartz tubes, show a smaller ρ_{anom} than do their samples. Moreover, the magnitude of the anomalous resistance does not vary as a function of either the zinc content or the state of anneal. Thus, no distinction is made in the figure between the data taken on a particular sample in its various stages of anneal (cold worked; 200°C for about two hours; 350° for about two hours). Distinction is made, however between the different samples consisting of pure copper (American Smelting and Refining Company high-purity—nominal 99.999 percent—copper stock[2] treated and prepared in the same manner as the alloys), of ~0.1 atomic percent zinc, and of ~0.5 atomic percent zinc in American Smelting and Refining copper. Figure 1 clearly shows that ρ_{anom} *vs* temperature is the same for all samples. There is thus no evidence allowing one to ascribe the observed anamolous temperature-dependent resistivity to zinc in either of the alloys.

The anomalous temperature-dependent resistivity observed in the particular sample of "pure" copper used in these experiments is larger than any we have observed in other samples of pure American Smelting and Refining copper[3] even though it is somewhat less than that reported by Gerritsen and Linde for their copper. The indication is, then, that our method of preparing the alloys, to which the pure copper is also subjected, may result in picking up very small amounts of minimum-producing impurities.

A more detailed report of these measurements, along with measurements in the hydrogen temperature range and on higher percentage zinc alloys, will be given soon.

[1] A. N. Gerritsen and J. O. Linde, Physica **18**, 877 (1952).
[2] Smith, Smart, and Phillips, Trans. Am. Soc. Mech. Engrs. **143**, 272 (1941).
[3] R. W. Schmitt and M. D. Fiske, Phys. Rev. **96**, 1445 (1954).

Correspondence between Semiclassical and Quantum Treatments of Coulomb Excitation*

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FROM the experimental evidence[1] regarding correctness of the dependence of the cross section on incident energy, it is not possible to conclude directly that the absolute value of the cross section is correctly given by the usual semiclassical treatment, referred to as SCT. In this and the following notes only the simple case of one nuclear proton, initially in an *s* state, being responsible for the interaction, is considered, the generalization to several nuclear protons being irrelevant to the question of accuracy of the SCT. The first order Born approximation with the nuclear quadrupole interaction as the small quantity is taken to be adequate.

The collision cross section for the reaction can be represented as

$$\sigma = (4/25)(mk_f/v_i\hbar^3)Z_1^2e^2B(2)\mathfrak{A}, \tag{1}$$

$$\mathfrak{A} = \Sigma \mathfrak{A}_L, \tag{2}$$

$$\mathfrak{A}_L = 16\pi^2 k_i^{-2}k_f^{-2}\left\{\frac{3L(L+1)}{2(2L+1)}\right.$$
$$\times\left[\left|\int F_{L-1}(k_ir)F_{L+1}(k_fr)r^{-3}dr\right|^2\right.$$
$$\left.+\left|\int F_{L+1}(k_ir)F_{L-1}(k_fr)r^{-3}dr\right|^2\right]$$
$$\left.+\frac{L(L+1)(2L+1)}{(2L-1)(2L+3)}\left|\int F_L(k_ir)F_L(k_fr)r^{-3}dr\right|^2\right\}.$$
$$= 16\pi^2\mathfrak{C}_L. \tag{2'}$$

$$B(2) = 5e^2\left|\int_0^\infty r_p^4 R_i(r_p)R_f(r_p)dr_p\right|^2, \tag{3}$$