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LETTERS TO THE EDITOR

EFFECT OF STRESS ON RESISTIVITY-STRAIN RELATION OF ALUMINIUM

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In recent years torsional deformation with superimposed tensile load has attracted attention of a number of investigators[1]. This combined mode of deformation makes possible the production of large deformation[2]. According to Kovacs and Nagy[3] the discrepancy between the theory of specific electrical resistivity change with strain and the experimental results arises from the low amount of deformation reached before fracture and without any dislocation contribution.

The object of this work was to investigate the effect of various tensile stresses superimposed during twisting on the resistivity — strain relation of 99.7 % pure aluminium. The literature seems lacking in this respect.

In this work 99.7 % pure Al wires 0.05 cm in diameter and 150 cm long were used. The investigated Al samples contained the following impurities:

	Fe	Si	Mg	Cu	Mn and Ca
Wt %	0.25	0.05	0.92	0.005	small traces

The samples were first annealed in an evacuated silica tube at selected temperatures 250 °C, 350 °C and 500 °C for 5 hours and then furnate cooled to room temperature. The annealed samples were subjected to uniform twisting at room temperature and under various imposed constant tensile

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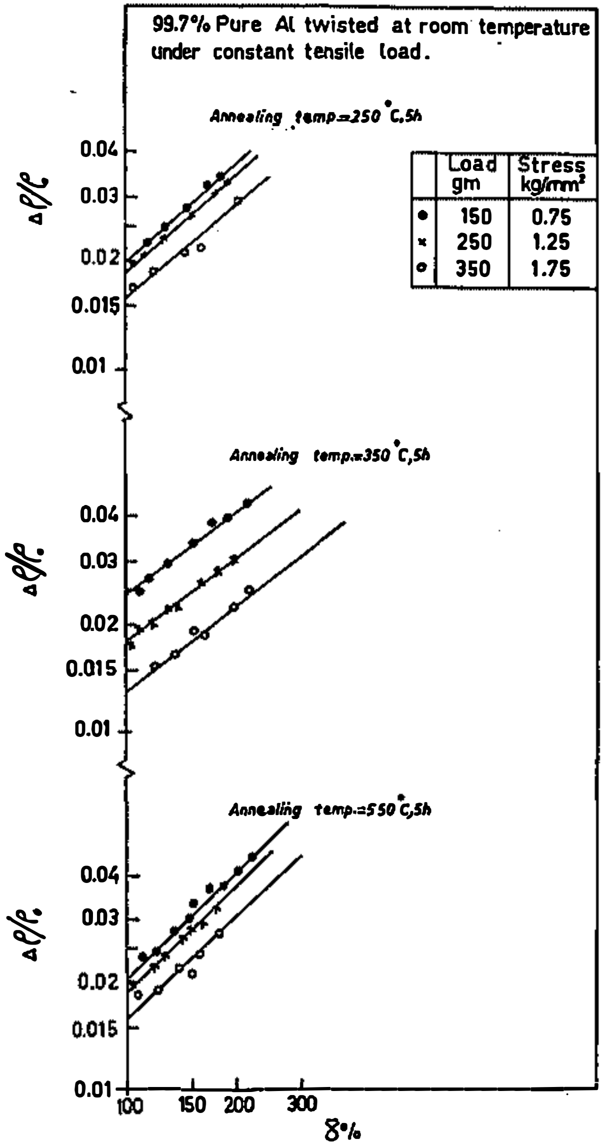

Fig. 1 Log plots of increase in resistivity vs. per cent total mean shear strain

loads 150, 250 and 350 g. These loads did not exceed half of the yield stress of the samples. Changes in the length were determined with micrometer microscope with accuracy better than 0.01 mm. The electrical resistance of the samples was measured at room temperature using Kelvin double bridge sensitive to 10^{-7} ohm. The relative change in resistivity was calculated from the formula (after Ceresara et al.[5])

$$\frac{\Delta \rho}{\rho_0} = \frac{\Delta R}{R_0}\left(1 - 2\frac{\Delta L}{L_0}\right) - \frac{2\Delta L}{L_0}, \tag{1}$$

where ρ_0 and R_0 are the resistivity and resistance of the sample of the initial length L_0.

The total shear strain γ for twisting under tensile stress was calculated as

$$\gamma = \alpha \frac{N D_0}{L_0} + \beta \frac{\Delta L}{L_0}, \tag{2}$$

where N is the number of turns of twist and ΔL is change in the length associated with twisting of the sample of initial length L_0 and diameter D_0. The constants α and β were taken as $2\pi/3$ and 3 respectively.

The dependence of the specific resistivity with strain is given by the empirical formula[7]

$$\Delta \rho = C \gamma^P, \tag{3}$$

where $\Delta \rho$ is change in the resistivity resulting from a mean shear strain γ, while C and P are constants. The constant C is composed from the contribution of point defects C_v, and from the contribution of dislocations C_d to the extraresistivity

$$C = C_v + C_d.$$

In the log diagram the equation (3) gives a straight line with the intercept log C and the slope P. Fig. 1 shows log plots of relative change in resistivity vs. per cent shear strain. At each annealing temperature and at various loads, the straight lines are almost parallel, with the slope P equal to the mean value of 0.82. The values of coefficient C are given in Table 1.

Table 1

Load g	150	250	350	
Values of C	0.0512	0.0487	0.0387	Annealing at 250 °C
μΩ cm	0.0612	0.0473	0.0333	Annealing at 350 °C
	0.052	0.0495	0.0407	Annealing at 500 °C

Peiffer and Stevenson[8], Kovacs and Nagy[14] have shown that the difference in values of the coefficient C obtained by various investigators is mainly due to different thermal and mechanical history of the investigated Al samples.

The value of the exponent P determined from our experiments (Fig. 1) at room temperature and at large deformation suggests[3,9], that most of the contribution to the extraresistivity arises from dislocations left in the metal.

It is evident from the Table 1 that the value of the coefficient C decreases with the increase of the tensile load and from the Fig. 1 that relative change in resistivity at a given shear strain also decreases with this change of conditions. This effect may be attributed to the decrease in dislocation density through the enhanced cross-slip mechanism during twisting. The cross-slip mechanism which is stress dependant, induces annihilation of screw dislocations on intersecting slip planes. The resulting decrease of the number of electron scatterers leads to the decrease of the electrical resistance.

The obtained values of C and P are of the same order of magnitude as those published and given in Table 2.

Table 2

Investigator	C μΩ cm	P	Temp. of determination	Purity of Al
Peiffer[9]	0.166	—	78 °K	Contains 140 P.P.m imurities
Winterberger[10]	0.021	1.00	78 °K	" " "
Pistorius[11]	—	1.3	78 °K	99.999 %
Ceresara et al.[5]	0.068	1.3	78 °K	99.995 %
Swanson[12]	0.66	1.6	4.2 °K	Zone refined
Martin and Welton[13]	0.729	1.76	77 °K	99.999 %

Peiffer and Stevenson[8] calculated the constants C_v and C_d and obtained values given in Table 3.

Table 3

Investigator	C_v μΩ cm	C_d μΩ cm	Temp. of determination	Purity of Al
Peiffer and Stevenson	4×10^{-3} 12×10	5.35×10^{-3} 9.1×10	Room temp. 78 °K	Al contains 140 P.P.M

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