

Surface scattering and DC size effects in aluminium

Autor(en): **Romero, J. / Huguenin, R.**

Objektyp: **Article**

Zeitschrift: **Helvetica Physica Acta**

Band (Jahr): **62 (1989)**

Heft 6-7

PDF erstellt am: **20.09.2024**

Persistenter Link: <https://doi.org/10.5169/seals-116082>

Nutzungsbedingungen

Die ETH-Bibliothek ist Anbieterin der digitalisierten Zeitschriften. Sie besitzt keine Urheberrechte an den Inhalten der Zeitschriften. Die Rechte liegen in der Regel bei den Herausgebern.

Die auf der Plattform e-periodica veröffentlichten Dokumente stehen für nicht-kommerzielle Zwecke in Lehre und Forschung sowie für die private Nutzung frei zur Verfügung. Einzelne Dateien oder Ausdrucke aus diesem Angebot können zusammen mit diesen Nutzungsbedingungen und den korrekten Herkunftsbezeichnungen weitergegeben werden.

Das Veröffentlichen von Bildern in Print- und Online-Publikationen ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Die systematische Speicherung von Teilen des elektronischen Angebots auf anderen Servern bedarf ebenfalls des schriftlichen Einverständnisses der Rechteinhaber.

Haftungsausschluss

Alle Angaben erfolgen ohne Gewähr für Vollständigkeit oder Richtigkeit. Es wird keine Haftung übernommen für Schäden durch die Verwendung von Informationen aus diesem Online-Angebot oder durch das Fehlen von Informationen. Dies gilt auch für Inhalte Dritter, die über dieses Angebot zugänglich sind.

Surface Scattering and DC Size Effects in Aluminium

J Romero and R Huguenin

Institut de Physique Expérimentale, Université de Lausanne, BSP, 1015 Lausanne, Switzerland

Abstract. *When the mean free path $\lambda_{\infty}(T)$ is of the order or smaller than the thickness d of the sample, the DC electrical resistivity ρ shows size effects and depends on the quality of the sample surface, polished or rough. We have performed high resolution measurements (1-10 ppm) of ρ in the temperature range 1.2 K - 9 K in Aluminium samples showing size effects. The surface was changed from rough to polished in a controlled and reproducible way by electropolishing and chemical treatments, showing that scattering at the sample surface is partially specular in contrast to the usual assumption of diffuse scattering. These results are compared with Soffer's theory.*

The first theory of size effects in DC electrical resistivity $\rho(d,T)$ was proposed by Fuchs [1] assuming as a boundary condition to solve Boltzmann equation that a constant fraction $0 \leq p \leq 1$, called the specularly parameter, of the incident electrons on the sample surface was specularly scattered. A more refined model of p based on an analogy with light scattering by surfaces was proposed by Soffer [2]. In this model $p(\theta) = \exp(-16\pi^2 r^2 \cos^2 \theta)$, θ being the angle between the direction of the incident electron and the surface normal and $r = h/\lambda_e$ the roughness (h the rms of the asperities and λ_e the electron wavelength). Interpreting the experimental results on $\rho(d,T)$ it has usually been assumed [3] that $p=0$ for Al because the oxide formed immediately on the surface after exposure to air was supposed to yield a rough surface for the scattering of conduction electrons. This point is however questionable and our results show that scattering is partially specular.

The $\rho(d,T)$ data are taken in a high purity monocrystal (RRR=39400). The sample preparation and the experimental setup allowing high resolution in the temperature range $1.2\text{K} \leq T \leq 9\text{K}$ has already been presented [4]. The state of the surface was changed from polished to etched by successive electropolishing and chemical treatments.

The results are presented in Fig. 1 where $\rho(d,T)$ is shown as a function of the thickness d . They are clearly distinct for polished and etched states of the surface. A fit has been made with Soffer's theory [2] and the curves are drawn with the following values of the parameters : a) $T=1.2$ K (residual resistivity) : $\rho_{\infty 0}(d,T) = 0.70 \pm 0.02$ p Ω m, $\lambda_{\infty 0} = 1055 \pm 35$ μ m, b) $T=9$ K : $\rho_{\infty}(9\text{K}) = 1.25 \pm 0.04$ p Ω m, $\lambda_{\infty}(9\text{K}) = 630 \pm 20$ μ m. In both cases the polished states are well described with $r=0.30$ and the etched ones with $r=3.0$. The $\rho_{\infty}\lambda_{\infty}$ values obtained are 0.74 ± 0.05 f Ω m² at 1.2 K and 0.79 ± 0.05 f Ω m² at 9 K, the small difference being insignificant.

In this representation it is difficult to decide between Soffer's and Fuchs' model for the specularly parameter. To conclude it would be necessary to examine the

surface resistivity in more detail, for example its temperature dependence. Notwithstanding one fact is established : the possibility to change in a controlled way the surface specularity. So, values of p different from 0 may result from surface treatments and must be taken into account in the interpretation of experimental $\rho(d,T)$. The scatter in the $\rho_{\infty}\lambda_{\infty}$ values collected by Bass [5] is probably very often due to misinterpretation of the experimental data assuming $p=0$.

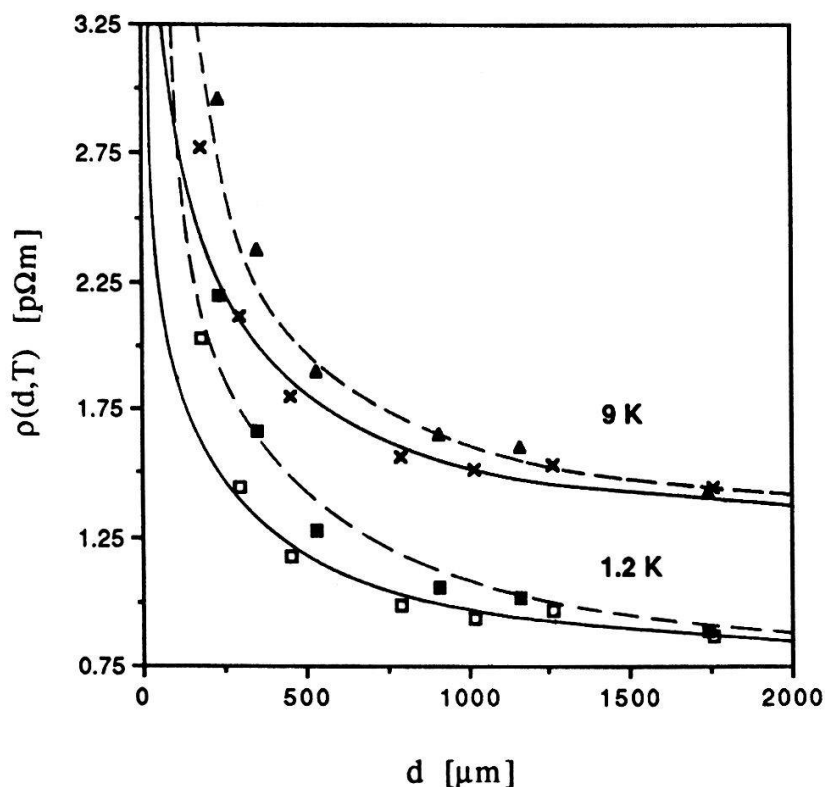


Figure 1. Resistivity $\rho(d,T)$ as a function of the thickness d for different states of the surface at $T=1.2$ K \square : polished, \blacksquare : etched, and at $T=9$ K \times : polished, \blacktriangle : etched.

The curves are fit to Soffer theory with the parameters at $T=1.2$ K $\rho_{\infty 0}=0.70$ p Ω m, $\lambda_{\infty 0}=1055$ μ m and at $T=9$ K $\rho_{\infty}=1.25$ p Ω m, $\lambda_{\infty 0}=630$ μ m. At both temperatures the value of the roughness parameter is $r(\text{polished})=0.30$ (full curves) and $r(\text{etched})=3.0$ (broken curves).

Evidence for $p \neq 0$ in Al has also been given by Sato and Yonemitsu [6] from transverse electron focusing (TEF) experiments which give more direct information on the specularity p than the resistivity. They have shown that p also depends on the crystallographic plane forming the sample surface.

The financial support of the Swiss National Science Foundation is gratefully acknowledged.

References

- [1] Fuchs K, Proc Camb Phil Soc **34** 100 (1938)
- [2] Soffer S B, J Appl Phys **38** 1710 (1967)
- [3] van Zytveld J B and Bass J, Phys Rev **177** 1072 (1969)
- [4] Romero J, van der Maas J and Huguenin R, Helv Phys Acta **61** 149 (1988)
- [5] Bass J, in *Landolt-Börnstein* vol 15, Springer-Verlag Berlin (1982)
- [6] Sato H and Yonemitsu K, J Phys F : Met Phys **16** 2053-62 (1986)