

**Zeitschrift:** Helvetica Physica Acta

**Band:** 62 (1989)

**Heft:** 6-7

**Artikel:** Surface scattering and DC size effects in aluminium

**Autor:** Romero, J. / Huguenin, R.

**DOI:** <https://doi.org/10.5169/seals-116082>

### **Nutzungsbedingungen**

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

### **Conditions d'utilisation**

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

### **Terms of use**

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

**Download PDF:** 17.01.2026

**ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>**

## 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  $\rho$  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  $\rho$  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.

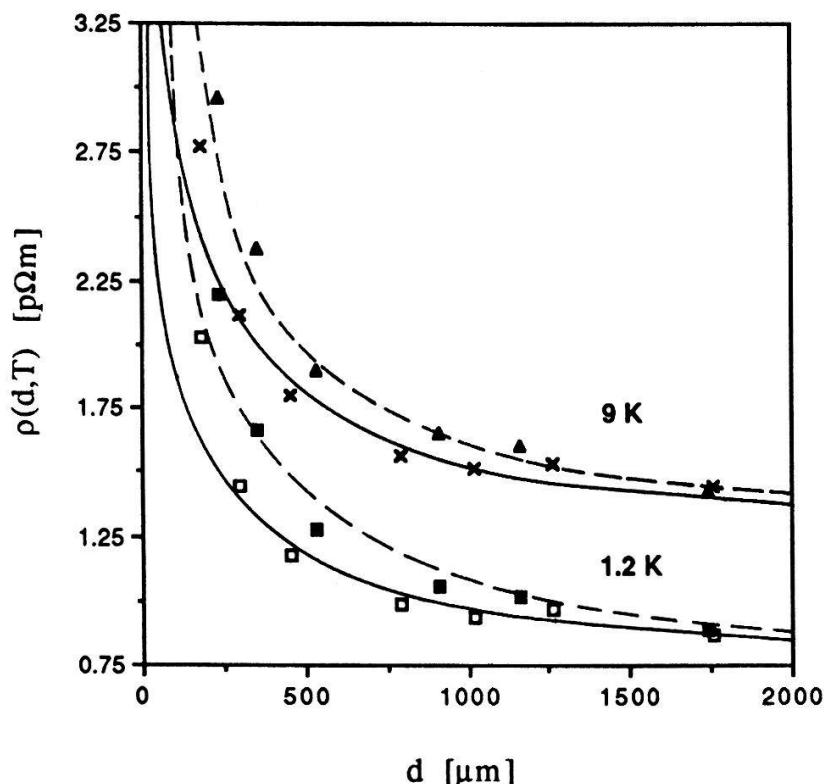
The first theory of size effects in DC electrical resistivity  $\rho(d,T)$  was proposed by Fuchs [1] assuming as a boundary condition to solve Boltzmann equation that a constant fraction  $0 \leq p \leq 1$ , called the specularity parameter, of the incident electrons on the sample surface was specularly scattered. A more refined model of  $p$  based on an analogy with light scattering by surfaces was proposed by Soffer [2]. In this model  $p(\theta) = \exp(-16\pi^2 r^2 \cos^2 \theta)$ ,  $\theta$  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  $\lambda_e$  the electron wavelength). Interpreting the experimental results on  $\rho(d,T)$  it has usually been assumed [3] that  $p=0$  for Al because the oxyde 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  $d$ . The 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)  $T=1.2 \text{ K}$  (residual resistivity) :  $\rho_\infty(0, T) = 0.70 \pm 0.02 \text{ } \mu\Omega\text{m}$ ,  $\lambda_\infty(0) = 1055 \pm 35 \text{ } \mu\text{m}$ , b)  $T=9 \text{ K}$  :  $\rho_\infty(9 \text{ K}) = 1.25 \pm 0.04 \text{ } \mu\Omega\text{m}$ ,  $\lambda_\infty(9 \text{ K}) = 630 \pm 20 \text{ } \mu\text{m}$ . 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  $0.74 \pm 0.05 \text{ } \text{f}\Omega\text{m}^2$  at 1.2 K and  $0.79 \pm 0.05 \text{ } \text{f}\Omega\text{m}^2$  at 9 K, the small difference being insignificant.

In this representation it is difficult to decide between Soffer's and Fuchs' model for the specularity 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  $\blacksquare$  : 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 $\Omega$ m,  $\lambda_{\infty 0}=1055$   $\mu$ m and at  $T=9$  K  $\rho_{\infty}=1.25$  p $\Omega$ m,  $\lambda_{\infty 0}=630$   $\mu$ 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)