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SHORT COMMUNICATION
Comments on Size Effects in Metallic Films

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In a recent paper[1] a new approximate expression for polycrystalline metal film resistivity has been compared to previously proposed expressions.[1–4] We attempt in this paper to discuss the validity of the theoretical formulation.

The well-known Fuchs–Sondheimer (FS) conduction model[5] is applicable to thin films in which background and film surface scatterings occur. The film resistivity ρ_F^{FS} is given by:[5]

$$\rho_F^{FS} = \rho_B \cdot [F(k,p)]^{-1} \tag{1}$$

where ρ_B is the bulk resistivity (i.e. the resistivity of an infinitely thick film), k the reduced thickness, p is the reflection coefficient at the film surfaces and F the usual size effect function or *FS* function. (Refer to Warkusz[1] (Eq. 2) and Sondheimer[5]).

Eq. (1) cannot be used to express the relation between the resistivity of a polycrystalline film ρ_F^{MS} and the resistivity ρ_g of an infinitely thick polycrystalline film in the Mayadas–Shatzkes model[6] (when background, grain-boundary and surfaces scatterings occur simultaneously) since the background relaxation time τ of the *F–S* model is replaced by a relaxation time τ^* representing the combined effect of background and grain-boundary scatterings (Refer to Mayadas and Shatzkes,[6] Eq. (76)). To obtain the total film resistivity in presence of both background, grain-boundary and surface scatterings, the relaxation time τ^* is then substituted for τ in the Boltzmann equation and in relations deduced from boundary conditions at film surfaces; hence, the obtained relation between ρ_F^{MS} and ρ_g (Mayadas and Shatzkes[6] Eq. (15) and Mola and Heras[7]) cannot be reduced to Eq. (1).

Consequently, all relations related to polycrystalline films which could be deduced from the following incorrect relation:[1]

$$\rho_F^{MS} = \rho_g \cdot [F(k,p)]^{-1} \tag{2}$$

are questionable. This is the case for Eq. (6) of Warkusz[1] and all derived equations. For large ranges of k, p and the physical parameter α[6] (specially in the usual thin films ranges); it is observed,[1] as expected, that this formulation markedly deviates from the theoretical Mayadas–Shatzkes (*MS*) relation. However no marked discrepancy is observed when $k \gg 1$ since the physical effect arising because of the geometrical limitation of the mean free path imposed by the film surfaces vanishes, i.e.

$$\rho_F^{MS}/\rho_g \approx 1.$$

It has been shown[8–15] that several methods exist to reduce *MS* expressions to analytical expressions and specially to Fuchs–Sondheimer expressions.[10,11,14] For instance an effective mean free path may be introduced, leading to a substitution of k by k_g where k_g is defined by:

$$k_g = k \cdot [G(\alpha)]^{-1} \tag{3}$$

with $G(\alpha) = \rho_0/\rho_g$ where ρ_0 is the resistivity of a single crystal, i.e. the resistivity that refers to background scattering. Hence, convenient expressions for ρ_F^{MS} could be[10,11,14]

$$\rho_F^{MS}/\rho_g = [F(k_g,p)]^{-1};$$
$$\rho_F^{MS}/\rho_0 = [F(k_g,p)]^{-1} \cdot [G(\alpha)]^{-1} \tag{4}$$

In the limit when k_g becomes large;[12]

$$\rho_F^{MS}/\rho_g \approx 1 + (1-p)k^{-1} \cdot \tfrac{3}{8}\, G(\alpha) \tag{5}$$

It has been previously shown[4] that an approximate expression for ρ_F^{MS} could be:

$$\rho_F^{MS}/\rho_g \approx 1 + (1-p)\, k^{-1} \cdot h(\alpha) \tag{6}$$

In the limiting k_g-range ($k_g \gg 1$) it appears that:

$$h(\alpha) \approx \tfrac{3}{8}\, G(\alpha) \tag{7}$$

Numerical data[4] have shown that the following relation

$$h(\alpha) = \tfrac{3}{8} \cdot G(\alpha) \tag{8}$$

proposed by Warkusz[1] leads to more significant deviation when we consider large α, p and k ranges than the model previously derived by Tellier and Tosser.[4]

Hence, we may conclude from the above discussions that the conduction model proposed by Warkusz is questionable.

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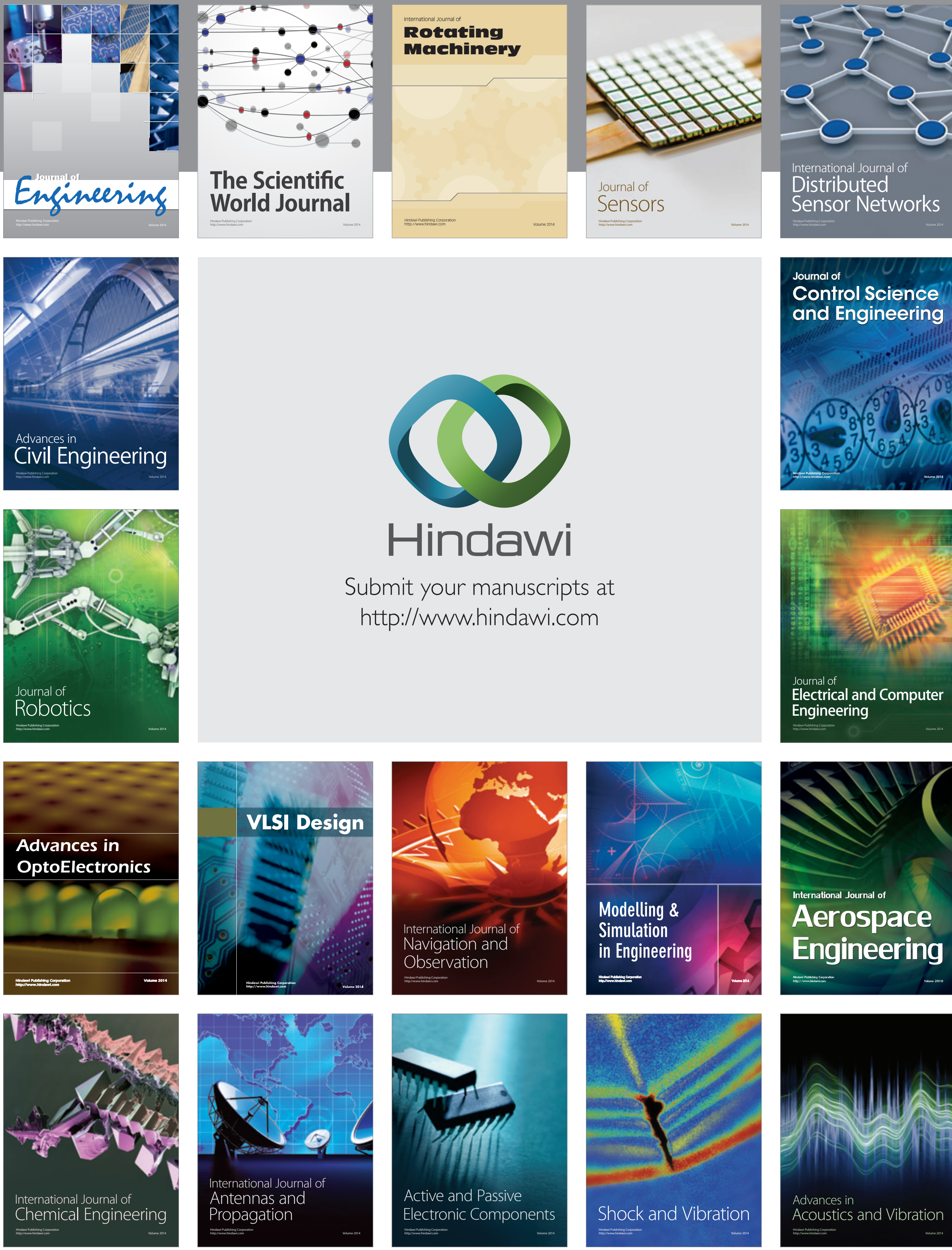
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