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The Effect of Phonons-Surface and Grain-Boundary Scattering on Electrical Properties of Metallic Ag

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Abstract

In this study, thickness has an inverse relationship with electrical resistivity and a linear relationship with grain boundary scattering based on utilizing the Fuchs-Sondheier and Mayadas-Shatzkces models, the M.S model represents all types of scattering that affect grain boundaries are two of the most important fundamental elements that used in estimating size effect according to theoretical studies.

While the F.S. model focusses on background scattering and grain boundaries, it also characterizes the scattering of conduction electrons on the surface of Materials since these surfaces have small grains that enable this kind of scattering. These two Models produced a basic equation in this work that takes into account the resistance of metals as well as the scattering of the surface to provide a metal resistivity-dependent experimental thickness. Value of thickness used to calculate electrical resistance by solving the Boltzmann Equation, where electrical resistivity inversely related to thickness. Wherefore the surface scattering coefficient p of Ag, which Fuchs-Sondheier and Mayadas-Shatzkces measured at 0.72, grain boundary reflection coefficient R which Mayadas-Shatzkces measured at R=0.001. According to this, silver is a good electrical conductor and used frequently in electrical and electronic circuits.

Keywords: MFP, reflection coefficient, electrical resistivity.

1. Introduction

Because it is useful for diverse purposes including electrical and electronic ones and because it is a metal with strong electrical conductivity ,silver has received a lot of attention in previous years[1,2,3]. That electrical properties are affected by metal concentration[4,5]. The value of thickness is used to calculate electrical resistance by solving the Boltzmann equation[6]. Then, using the F.S model which related to p and the M.S model which related to grain boundary reflection coefficient R, the electrical resistivity of silver was estimated[7]. The surface scattering coefficient utilized according to F.S theory, and conduction electron scattering occurs at the metal surface and interface increasing the intrinsic bulk resistivity of metals. Based on the following explanation of the resistivity ratio $\frac{\rho_f}{\rho_0}$ to the bulk metal:

$$\frac{1}{\phi(k)} = \frac{1}{k} - \frac{3}{2k^2}(1-p)\int_0^{\infty} \frac{1}{t^3} - \frac{1}{t^5}\,\frac{1-e^{-kt}}{1-pe^{-kt}}\,dt \qquad (1)$$

$$\frac{\rho_f}{\rho_0} = 1 + \frac{3}{8k}(1-p) \qquad (2)$$

ρ_f is the final resistivity,ρ_0 is the intrinsic resistivity, k is thickness that equal $(k = d\backslash L_0)$, d is the diameter, L_0 mean free path MFP, and p surface scattering coefficient.

The surface scattering and boundary reflection coefficients compute for the Mayadas-Shatzkces model-based condensed solution for the total resistivity of metals[4,8]. The Fuchs size effect and scattering at grain boundaries respectively are fundamental for the electrical resistivity of the conducting electron dependency on thickness[9].

$$\propto = \frac{L}{d}\,\frac{R}{1-R} \qquad (3)$$

The parameter R and $\propto$ used to estimate the coefficient of reflection at silver grain boundary that is equal to R=0.001, as annealing proceeded to encourage it measurements of grain and resistivity taken at various grain sizes:

$$\frac{\rho_f}{\rho_0} = 1 + \frac{3}{2}\propto \ll 1 \qquad (4)$$

The resistance of metals and Masada's - Shatzkces electron scattering for grain boundaries are estimated of Fuchs - Sondheier related to electron surface scattering in Eq. (2),
and Eq. (5) can fundamentally combine to get Equation (2)and (4) as:

$$\frac{\rho_f}{\rho_0} = 1 + \frac{3}{8k}(1-p) + \frac{3}{2}\propto \qquad k \gg 1, \propto \ll 1 \qquad (5)$$

These two models showed that silver is one of the metals that conduct electricity[10,11]. its temperature-dependent in terms of electrical resistivity increases as the thickness decreases[12,13,14,15]. which equal ($\rho_0 = 1.63 \times 10^{-8}\Omega m$) ,mean free path equal ($L_0 = 57nm$) ,and ($\rho_0 L_0 = 7 \times 10^{-16}\Omega m^2$) [1], also are three kinds of scattering: background, Grain boundary, and external surface boundary[7]. where the scattering substantially reduces the size effect[7].

2. Result and Discussion

The subsequent Eq.2 indicates which shown in **Figure (1)**, the electrical resistivity of silver is equivalent to thickness. Surface scattering coefficient estimated using the Fuchs-Sondheier model:

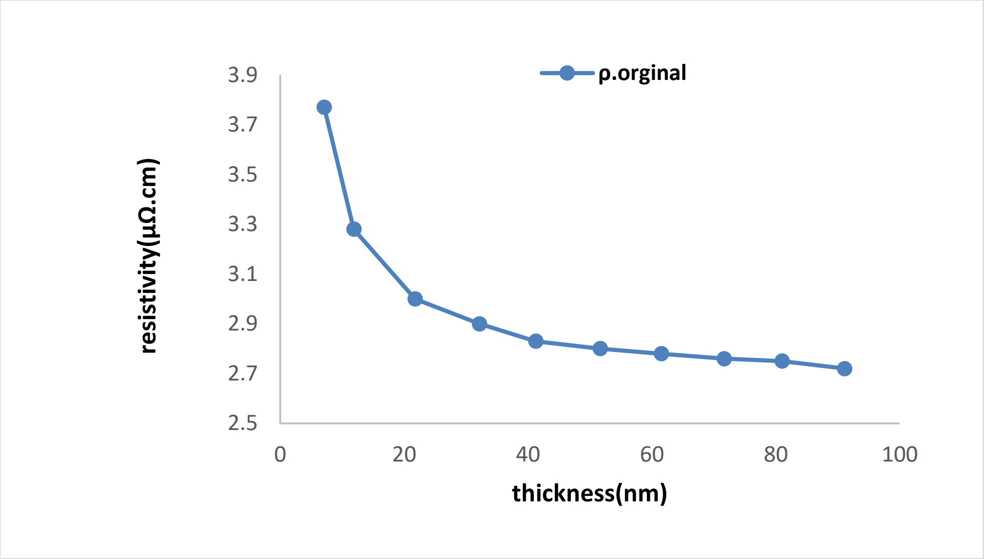

Figure.1. resistivity of metallic silver with thickness.

Resistivity in [y-axis], Thickness [x-axis], will take value for interception point equal{$7.46 \times 10^{-17}\ \Omega m^2$}, slope {$2.65 \times 10^{-8}\Omega m$} . In **Figure (2)** below:

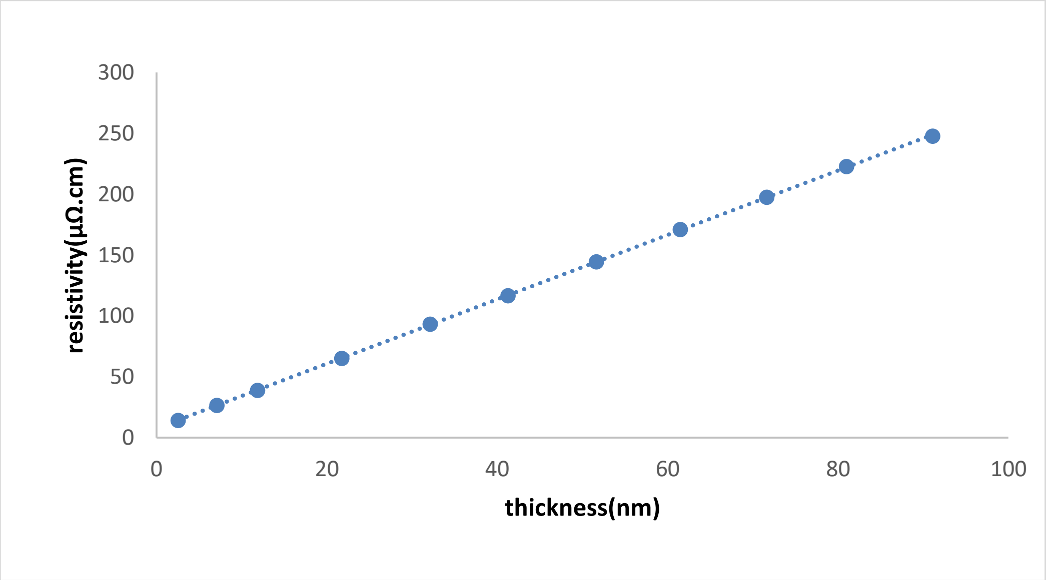

Figure 2. point of intersection with a silver thickness.

We now apply Eq. (1) to determine the silver surface scattering coefficient which is 0.72 due to the point defect, impurity, and vacancy[16]. In addition, using Eq. (1) we can determine a new resistivity $\rho_f$with scattering coefficient p then, as shown in **Figure (3)**, compared to the intrinsic resistivity ρ_0 for silver:

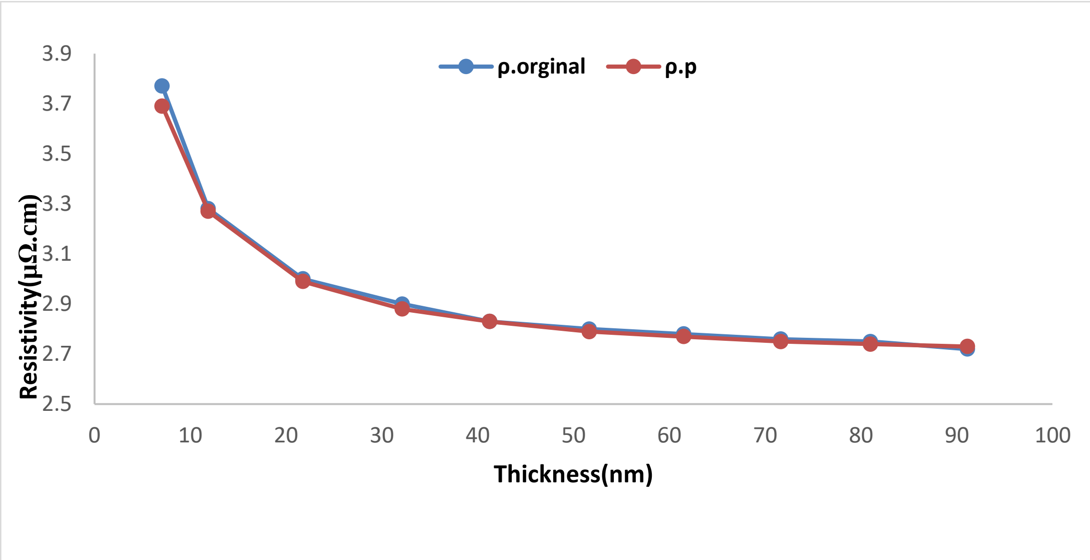

Figure3. Theoretical alteration of the resistivity & thickness of silver

Now, Eq. 5 calculated the silver Grain- boundary reflection coefficient, which based on the Fuchs-Sondheier and Mayadas-Shatzkces model.

In addition, the value of bulk resistivity ($\rho_0 = 1.63\mu\Omega.\text{cm}$) ,($L_0 = 57\text{nm}$), In ($\rho_0 L_0 = 7 \times 10^{-16}\Omega\text{m}^2$) [1]. As the result shown in the flowing **Figure (4)**, we applied reflection coefficient R and surface scattering coefficient p in Eq. 2 to calculate the new resistivity.

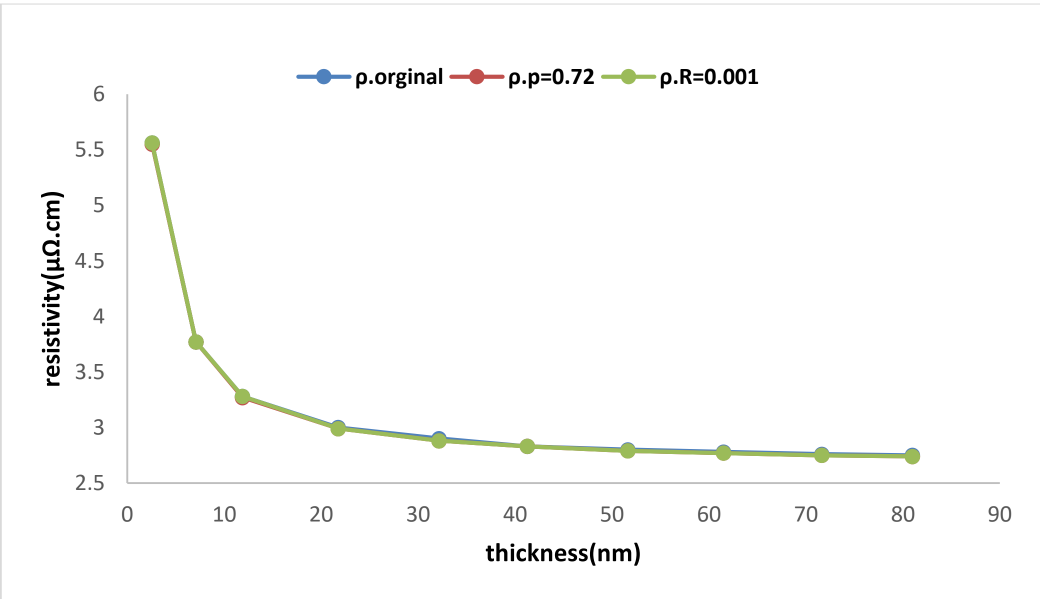

Figure 4.resistivity and thickness of silver.

3. Conclusion

The electrical resistivity of silver estimated in this study after the Boltzmann equation solved because silver metal has strong electrical conductivity which has many advantages, the most important of which is that it is applied in electronic and electrical circuits. Surface scattering coefficient is calculated using Eq. 2 which is based on the Fuchs-Sondheier model is p=0.72. Moreover, using Eq.5 which is based on the Fuchs-Sondheier and Mayadas-Shatzkces model grain -boundary reflection coefficient R=0.001 is calculated. finally, with applying the values of bulk resistivity($\rho_0 = 1.63\mu\Omega.\text{cm}$), ($L_0 = 57\text{nm}$), indicates that the electrical resistivity is inversely related to thickness and increasing as thickness decreases.

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