Question

Metallic Bond: Silver has an atomic mass of 108 u, a density of $10.5\times10^3\,kg/m^3$, and a Fermi energy of 5.51 eV. On the assumptions that each silver atom contributes one electron to the electron gas and that the mean free path of the electrons is 200 atom spacings, estimate the resistivity of silver. (The actual resistivity of silver at 20°C is $1.6\times10^{-8}\,\Omega\,m$.)

Solution

The resistivity ρ of a given sample of a metal at a given temperature (eq 10.16 in the text) is

$$\rho = \frac{mv_F}{ne^2\lambda}$$

Where

$$v_F = \sqrt{\frac{2\epsilon_F}{m}} = \sqrt{\frac{2\times5.51\times1.6\times10^{-19}}{9.1\times10^{-31}}} = 1.392\times10^6\,m/s$$

$$n = \frac{10.5\times10^3}{107.9u} = \frac{10.5\times10^3}{107.9(1.66\times10^{-27})} = 5.862\times10^{28}\,/m^3 \qquad \text{(Electron density= no. of Ag atoms)}$$

$$\lambda = 200\times.289\,nm = 5.78\times10^{-8}\,m \qquad *$$

Hence

$$\begin{aligned}\rho &= \frac{(9.1\times10^{-31})(1.392\times10^6)}{(5.862\times10^{28})(1.6\times10^{-19})^2(5.78\times10^{-8})}\\ &= \frac{1.267\times10^{-24}}{8.674\times10^{-17}}\\ &= 1.46\times10^{-8}\ \Omega\,m\end{aligned}$$

The resistivity of silver is estimated as $1.46\times10^{-8}\ \Omega\,m$

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* I've looked up the atomic spacing for Ag on the Internet, if the value stated for Cu ($0.26\,nm$) in the text is used the answer is closer to the $1.64\times10^{-8}\ \Omega\,m$ given in the book. The actual resistivity of a metal sample depends on its temperature and concentration of defects.