Relationship of the resistivity with the specific heat.

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Abstract

In this article, the relationship between resistivity and the specific heat of a conductor is studied. It is known that the resistivity of a conductor increases when the temperature of the conductor increases. And the specific heat of a material is a function of temperature.

Keywords: resistivity, specific heat, Joule effect.

Introduction

The specific heat is a physical quantity that is defined as the amount of heat that must be supplied to the mass unit of a thermodynamic substance or system to raise its temperature by one unit.

The specific heat capacity c (T) is a function of the temperature of the system. This function is increasing for most substances (except for monatomic and diatomic gases). This is due to quantum effects that make the vibration modes quantized and only accessible as the temperature increases. Once the function c (T) is known, the amount of heat associated with a change in the temperature of the system from the initial temperature T_o to the final temperature T_f is calculated by means of the following integral:

$$Q = m \int_{T_o}^{T_f} c dT$$

Where m is the mass.

In a range where the specific heat is approximately constant, the above formula can be written simply as:

$$Q \approx mc\Delta T$$

On the other hand, resistivity is the specific electrical resistance of a certain material. It is designated by (ρ)

$$\rho = R\frac{S}{\iota}$$

Where R is the electrical resistance, S the cross-sectional area of the conductor and ι the length of the conductor.

Its value describes the behavior of a material against the passage of electric current: a high value of resistivity indicates that the material is bad conductor while a low value indicates that it is a good conductor.

The resistivity is the inverse of the electrical conductivity; therefore, $\rho = \frac{1}{\sigma}$ In general, the magnitude of the resistivity (ρ) is the proportionality between the electric field **E** and the conduction current density **J**

$$\boldsymbol{E} = \rho \boldsymbol{J}$$

Generally the resistivity of metals increases with temperature, while the resistivity of semiconductors decreases with increasing temperature.

The resistance of a conductor changes with the temperature, according to the following expression.

$$R_{t_f} = R_{t_o}\left(1 + \alpha\left(T_f - T_o\right)\right)$$

Where R_{t_o} is the initial resistance, α coefficients of variation of resistance per temperature degree T_o the initial temperature and T_f the final temperature.

The Joule effect is the phenomenon by which if a conductor circulates electric current, part of the kinetic energy of the electrons is transformed into heat due to the shocks they suffer with the atoms of the conductive material through which they circulate, raising the temperature of the same. The movement of electrons in a cable is disordered; this causes continuous collisions with the atomic nuclei and, as a consequence, a loss of kinetic energy and an increase in temperature in the cable itself.

The released heat emitted by a resistance in which an electric current flows, is expressed as.

$$Q = 0.24I^2Rt$$

Where R is the resistance, I the intensity of current and t the time.

Ratio of the resistivity of a material, with its specific heat.

$$Q = m\int_{T_o}^{T_f} cdT$$

$$Q = 0.24I^2Rt$$

Matching both expressions

$$m\int_{T_o}^{T_f} cdT = 0.24I^2Rt$$

Expressing resistance in terms of resistivity.

$$m\int_{T_o}^{T_f} cdT = 0.24I^2t\frac{\rho \iota}{S}$$

Solving the resistivity

$$\rho = \frac{mS}{0.24I^2\iota t}\int_{T_o}^{T_f} cdT$$

Hence, the resistivity of a conductor changes with the passage of an electric current I, during a time t, which generates a temperature change of T_o or T_f and depends on the mass m, the cross-sectional area S, the length of the conductor ı and the specific heat c (T) of the conductor.

Conclusions

The expression was presented

$$\rho = \frac{mS}{0.24 I^2 \iota t} \int_{T_o}^{T_f} c dT$$

That allows relating the resistivity of a conductor with its specific heat.

In a future work we will seek to study this same relationship at the quantum level, considering the power dissipated in the Joule effect, expressed by the triple integral.

$$\iiint_V \vec{\boldsymbol{J}} * \vec{\boldsymbol{E}} dV$$

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