

Determination of gadolinium thermal conductivity using experimentally measured values of thermal diffusivity

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Abstract. The thermal diffusivity of gadolinium in the temperature range 25–900 °C has been measured with application of the laser flash method. The thermal conductivity has been deduced by using published specific heat and density data. Despite the debated values at room temperature, the thermal conductivity of gadolinium is very low compared with that of almost any other pure metal.

1. Introduction

The thermal conductivity of gadolinium has been studied by Arajs and Colvin (1964) and Aliev and Volkenstein (1966) at low temperatures (–268–27 °C), by Legvold and Spedding (1954) at 18 °C and by Novikov *et al* (1977) around the solid–liquid phase transition (827–1827 °C). The absence of values in the intermediate temperature range 25–900 °C has stimulated experimental interest. We present results calculated on the basis of the thermal diffusivity values, obtained experimentally by applying the laser flash method.

2. Theory

The laser flash method for determining the thermal diffusivity and heat capacity of metallic compounds has been described in detail elsewhere (Parker *et al* 1961). Consequently, only a brief recall of the method is given here.

A high-intensity short-duration laser pulse is absorbed by the front surface of a specimen a few millimetres thick. The resulting temperature evolution on the rear surface is measured by a thermocouple and is recorded by computer.

Assuming no heat losses and considering one-dimensional heat propagation, Carslaw and Jaeger (1959) resolved the heat conduction equation

$$\frac{\partial T(x, t)}{\partial t} = D \frac{\partial^2 T(x, t)}{\partial x^2} \quad (1)$$

where D is the thermal diffusivity.

Using this solution and supposing that the energy density of the laser pulse is instantaneously and uniformly absorbed, Parker *et al* (1961) obtained the following expression for the thermal diffusivity:

$$D \approx \frac{1.38L^2}{\pi^2 t_{1/2}} \quad (2)$$

where L is the specimen thickness and $t_{1/2}$ is the time required for the back surface to attain half the maximum temperature rise.

In reality, the specimen is not perfectly thermally insulated. If one takes into account heat losses as well as the propensity of the sample to return to the environmental temperature then a slightly modified expression is obtained (Cowan 1963):

$$D = \frac{\gamma L^2}{t_{1/2}} \quad (3)$$

where γ is a coefficient given in figure 1 as a function of the ratio $T_{5t_{1/2}}/T_{\max} \cdot T_{5t_{1/2}}$ is the temperature at time $5t_{1/2}$ and T_{\max} is the maximum temperature reached in the back face, just after the absorption of the laser pulse.

Consequently, knowledge of $L(T)$ and experimental measurements of $t_{1/2}$, $T_{5t_{1/2}}$ and T_{\max} can give the thermal diffusivity according to equation (3). The thermal conductivity $K(T)$ is then obtained by

$$K(T) = \rho(T)D(T)C_p(T) \quad (4)$$

where $\rho(T)$ and $C_p(T)$ are the density and heat capacity respectively. Knowledge of the amount of energy absorbed in the front surface during each laser pulse is not necessary for the determination of the diffusivity, provided that $C_p(T)$ is known.