

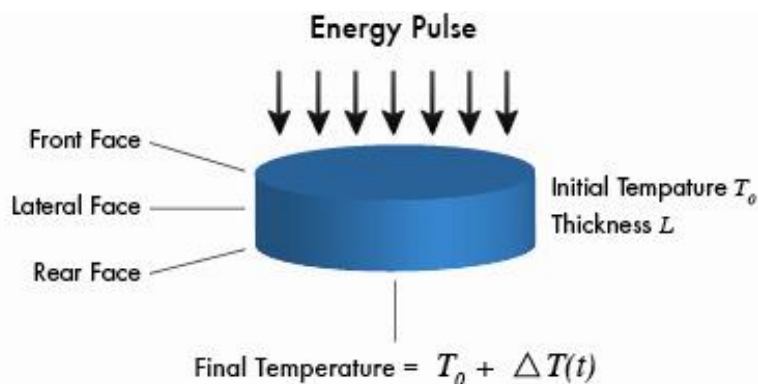
## Thermal Diffusivity by the Flash Method

The thermal diffusivity ( $\alpha$ ) of a medium is the thermophysical property that determines the speed of heat propagation by conduction during changes of temperature with time. The higher the thermal diffusivity, the faster the heat propagation. The thermal diffusivity is related to the thermal conductivity ( $\lambda$ ), specific heat ( $C_p$ ) and density ( $\rho$ ) as follows:

$$\alpha = \frac{\lambda}{\rho C_p}$$

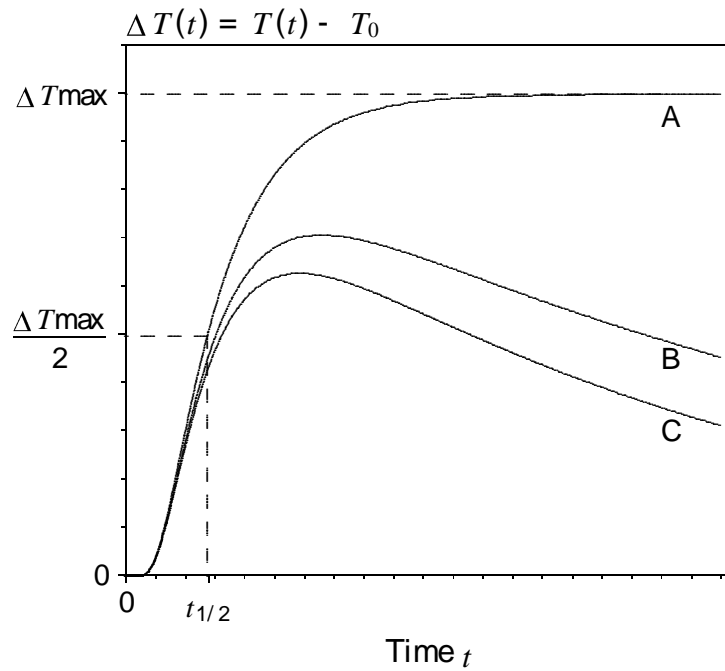
According to the above definition, the thermal diffusivity affects any conductive transient heat transfer process within the medium. It has the dimension length<sup>2</sup>/time and is expressed in the unit m<sup>2</sup>/s.

The most popular method used for measuring thermal diffusivity is the flash method. It has the advantage of being fast while providing values with excellent accuracy and reproducibility. After the sample has been stabilized at a desired temperature  $T_0$ , a nearly instantaneous pulse of energy (usually laser or other discharge source) is deposited on its front face, and the temperature increase on the rear face of the sample is recorded as a function of time (Fig. 1). The thermal diffusivity is then determined from this thermogram.



**Figure 1:** Schematic of the flash method

The characteristic shapes of the temperature increase curves are depicted in Fig. 2. If no heat loss is involved, the temperature of the rear face will rise to a maximum and remain at that level indefinitely (Curve A). However, with increasing heat losses, the temperature on the rear face decreases after reaching a maximal value (Curves B and C).



**Figure 2:** Temperature increase for various experimental conditions

The original method proposed by Parker (1) assumes an isotropic and adiabatic sample (no heat loss). The thermal diffusivity is determined from the thickness ( $L$ ) of the sample and the time ( $t_{1/2}$ ) the thermogram takes to reach half of the maximal temperature increase:

$$\alpha = 0.1388 \frac{L^2}{t_{1/2}}$$

Since this method assumes ideal conditions of adiabatic sample and instantaneous pulse heating, it is somewhat limited in applicability. To make it more suitable to experimental conditions, other methods have been introduced over the years, which account for heat losses, finite pulse duration, non-uniform pulse heating, and composite (non-homogeneous) structures.

Major advantages of the method are that:

- it requires a very small sample, usually 12 mm diameter and few millimeters thick
- it is very fast, the actual measurement takes few seconds
- the same instrument can be made to test a very broad range of thermal diffusivities ( $10^{-3}$  to  $10$   $\text{cm}^2/\text{s}$ ), while usual thermal conductivity test instruments barely cover 10:1 ratio range
- it can be used, with proper precautions, to also measure other thermophysical properties (specific heat, thermal conductivity, etc.)
- it can be used to test samples up to much higher temperatures than steady state methods, even through the melt in some cases

Major disadvantages of the flash method are that:

- the equipment is usually expensive due to the heat pulse generation, the optical detection and the high speed data acquisition;
- porous and non-homogeneous materials require special care to properly process the thermogram.

## **REFERENCES**

[1] W.J. Parker, R.J. Jenkins, et al., "A Flash Method of Determining Thermal Diffusivity, Heat Capacity, and Thermal Conductivity", U.S. Navy Report USNRDL-TR-424, May 1960.

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