Thermal Diffusivity Measurements of Fibres and Foils Using Lock-In Thermography

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Lock-in thermography has been used to measure the thermal diffusivity of a wide variety of bulk materials. When heating the sample surface with a focused and modulated laser beam, the in-plane thermal diffusivity can be measured by recording the amplitude and phase of the surface temperature as a function of the distance to the heating spot. In fact, there is a linear relation between the phase of the surface temperature and the distance to the heating spot, whose slope (m) is given by $m = (\mathrm{p}f/D)^{0.5}$, where f is the modulation frequency and D is the thermal diffusivity. However, when measuring small-sized materials (such as fibres and foils), the influence of heat losses, which is enhanced as the surface-to-volume ratio increases, must be taken into account.

In this work, we have used an IR camera to measure the thermal diffusivity of plates (both isotropic and anisotropic) as thin as 10 microns and thin wires with diameters as small as 7 microns. In order to increase the spatial resolution, two extension rings have been placed between the lens and the camera body. In this way, each pixel measures the temperature average over a square of 42 microns on a side, above the diffraction limit (35 microns). Both thermal conducting and isolating materials have been measured. In particular, a value of $D = 0.32 \pm 0.02\ \mathrm{mm}^2/\mathrm{s}$ has been obtained for human hair. This value is in good agreement with the thermal diffusivity of keratin, which is the main component of hair. Moreover, the dependence of the glass transition temperature of human hair on water content has been investigated, by using an optical cryostat with sapphire windows (transparent to IR).

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