PHOTOTHERMAL APPLICATIONS TO THE THERMAL ANALYSIS OF SOLIDS

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Major application of optically-induced thermal waves to the thermal and thermodynamic analysis of solids are reviewed. The spectrum of available techniques, from the conventional photoacoustic detection to novel photothermal laser probing and frequency multiplexing is discussed, and their utilization for the measurement of thermophysical thermal transport-related parameters of solids is presented. These include the thermal diffusivity, effusivity, conductivity and specific heat. The ability of photothermal methods to perform thermal analysis on large classes of solids, including conducting and insulating bulk materials, crystals, layered porous and coated structures, thin films and inhomogeneous thermal profiles is highlighted. Finally, special capabilities of photothermal analysis, such as the monitoring of surface thermodynamic phenomena and phase transition studies, including high-Tc superconductors, are described in order to give a complete overview of the rich potential of photothermal-based methodologies.

Exposure of a sample to radiation results in local heating due to absorption and subsequent thermalization of the incident radiation. The extent of absorption and the thermalized volume fraction depend on the interplay between the absorption profile and the thermal transport properties of the material under investigation. If the irradiance of the incident radiation is modulated harmonically or pulsed, an oscillatory or transient heat source, respectively, is generated in the sample. Thermal waves are thus created,
which interact with the sample before being detected is one of several available photothermal sensing methods.[1–4] Due to thermal expansion acoustic waves are simultaneously launched into the sample and their detection is the object of various photoacoustic detection schemes, primarily through the intimate contact of the sample with an acoustic piezoelectric transducer.[5, 6] These photoacoustic phenomena are outside the scope of this review, with the exception of the conventional microphonic photoacoustic (PA) detection [7] which, in several applications important to thermal analysis, uses acoustic waves primarily as simple, passive carriers of thermal-wave signals to a remote microphone for detection. Depending on the physical principle(s) on which the thermal-wave sensor is operating, important photothermal (PT) schemes for thermal analysis to-date, besides PA detection, are laser beam deflection (or Mirage effect), photothermal radiometry, photopyroelectric detection, and laser-surface interaction based methods. These techniques are ideal for the thermal analysis of broad classes of matter, including fluids and gases. In this review, we will only examine solid phase applications. Although thermal waves may be generated in a sample through the incidence and nonradiative conversions of either modulated or pulsed optical energy, or even with electrons, ions or neutral particles, the great majority of thermal analyses has been performed with optical photon sources. Furthermore, depending on the mode of signal generation and detection, photothermal instrumentation schemes can be divided into synchronous (frequency-domain, FD), transient (time-domain, TD) and intermediate frequency-multiplexed (FM).

In Section I a brief overview of the PA methodology and selected applications to thermal analysis will be presented, followed, by PT methodologies, such as Mirage effect, Photothermal Radiometry and Photopyroelectric detection and applications to wide ranges of solids in Section II. Section III is a discussion of non-conventional photothermal application to thermal analysis, including phase transitions and laser-surface thermal interactions. These perspectives are aimed to indicate the potential of photothermal detection schemes and the role they are likely to play in the evolution of the field of Thermal Analysis.

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