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THE THEORY OF OBTAINING THIN SILICATE FILMS BY SEMICONDUCTORS, THERMAL AND LASER HEATING

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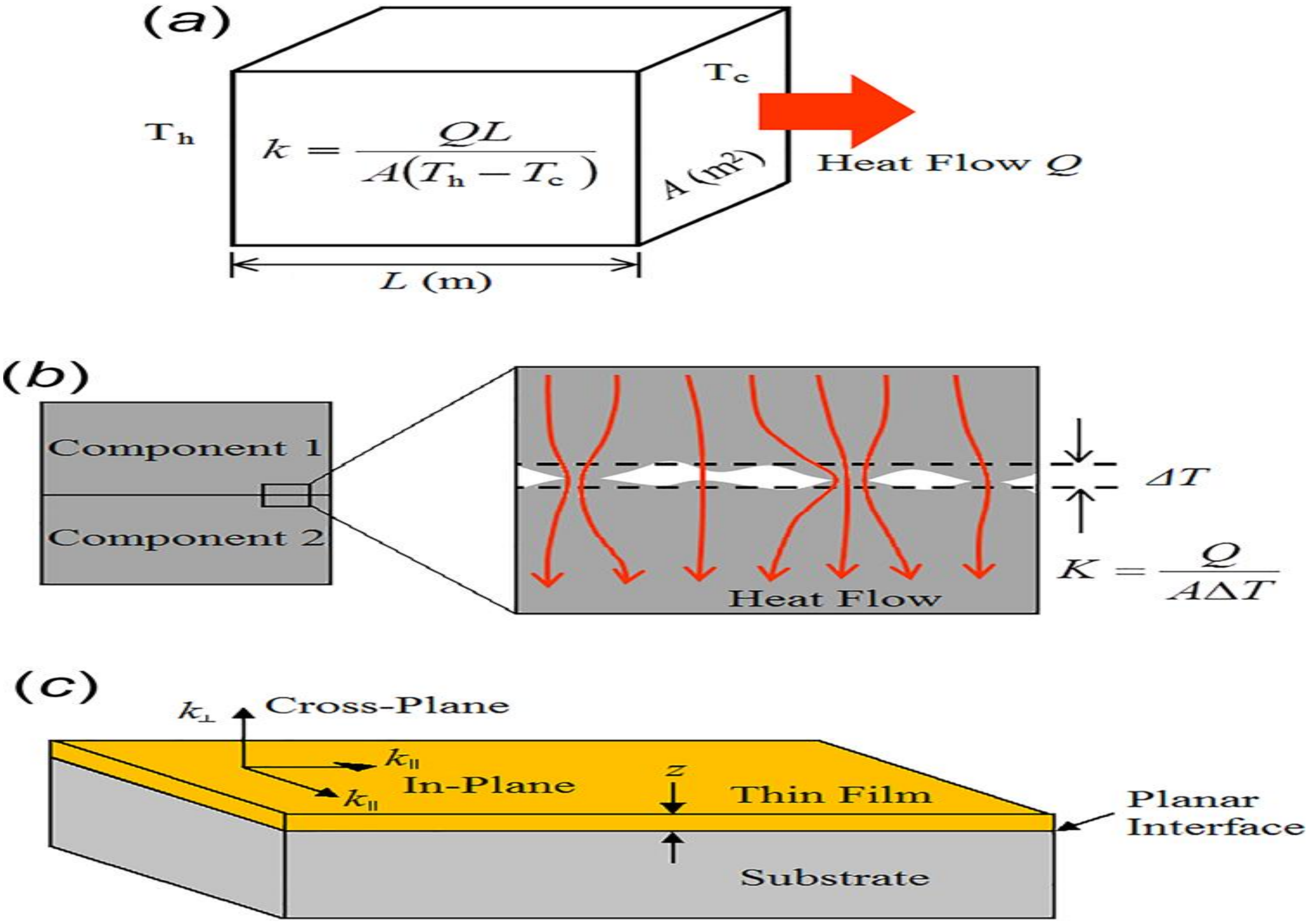
Abstract

Thermal conductivity (denoted as k, j, or k) measures the heat conducting capability of a material. As shown in Fig. 1(a), it can be defined as the thermal energy (heat) Q transmitted through a length or thickness L in the direction normal to a surface area A, under a steady-state temperature difference Th _ Tc. Thermal conductivity of a solid-phase material can span for several orders of magnitude, with a value of _0.015 W=mK for aerogels at the low end to _2000 W=mK for diamond and _3000 W=mK for singlelayer graphene at the high-end, at room temperature. Thermal conductivity of a material is also temperature-dependent and can be directional-dependent (anisotropic). Interfacial thermal conductance (denoted as K or G) is defined as the ratio of heat flux to temperature drop across the interface of two components. For bulk materials, the temperature drop across an interface is primarily due to the roughness of the surfaces because it is generally impossible to have “atomically smooth contact” at the interface as shown in Fig. 1(b). Interfacial thermal conductance of bulk materials is affected by several factors, such as surface roughness, surface hardness, impurities and cleanness, the thermal conductivity of the mating solids, and the contact pressure [1]. For thin films, the temperature drop across an interface can be attributed to the bonding strength and material difference. Note that thermal contact resistance and thermal boundary resistance (or Kapitza resistance [2]) are usually used to describe heat conduction capability of an interface in bulk materials and thin films, respectively. Interfacial thermal conductance is simply the inverse of thermal contact/boundary resistance. Knowledge of thermal conductivity and interfacial thermal conductance and their variation with temperature are critical for the design of thermal systems.

Introduction

In this paper, we review measurement techniques for characterizing thermal conductivity and interfacial thermal conductance of solid-state in both bulk and thin film forms. Extensive efforts have been made since the 1950s for the characterization of thermal conductivity and thermal contact resistance in bulk materials [3–8]. Table 1 summarizes some of the most commonly used measurement techniques, which in general can be divided into two categories: steady-state methods and transient methods. The steady-state methods measure thermal properties by establishing a temperature difference that does not change with time. Transient techniques usually measure time-dependent energy dissipation process of a sample. Each of these techniques has its own advantages and limitations and is suitable for only a limited range of materials, depending on the thermal properties, sample configuration, and measurement temperature. Section 2 is devoted to comparing some of these measurement techniques when applied for bulk materials. Thin film form of many solid materials with a thickness ranging from several nanometers to hundreds of microns has been extensively used in engineering systems to improve mechanical, optical, electrical, and thermal functionality, including microelectronics [9], photonics [10], optical coating [11], solar cells, and thermoelectrics [12]. Thin film materials can be bonded on a substrate (Fig. 1(c)), free-standing, or in a multilayer stack. When the thickness of a thin film is smaller than the mean free path of its heat carriers, which are electrons and phonons depending on whether the material is electrically conducting or not, the thermal conductivity of thin films is reduced compared to its bulk counterparts because of the geometric constraints. Thermal conductivity of thin films is usually thickness-dependent and anisotropic, where the heat conducting capability in the direction perpendicular to the film plane (cross-plane) is very different from that parallel to the film plane (in-plane), as shown in Fig. 1(c). The thermal conductivity of thin films also depends strongly on the materials.



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