Thermophysical Properties of Metal Films in the Nanometer Scale

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Generally, the thermophysical properties in an interfacial region depend on the structure. For instance, in an epitaxial superlattice, the disordered arrangement of atoms in the interfacial region results in a specific interfacial region of about a few nm and then, at this thickness, the thermal conductivity decreases significantly. In the present study, we focus our attention on the interfacial region of a metal film on a substrate.

We point out that in the measurement of thermophysical properties of a thin film on a thin substrate, it is better to carry out the measurement in the direction parallel to the interface as a function of the film thickness, because it is superior to analyze the thermophysical properties of the interfacial region in such an arrangement. We performed measurements of the thermal diffusivity of a Pt film deposited on a thin polyimide film as a function of film thickness by an ac calorimetric distance-variation method. To reduce the experimental error caused by the thickness distribution of the substrate, we applied a modified thermal diffusivity measurement, in which the differential method was employed; that is, we used a common substrate, and on one half of the substrate a metal film was deposited, while the other half was left open. In this method, thermal diffusivity measurements of the deposited sample region and of the substrate region were carried out at the same time and, then, the thermal conductivity of the thin film could be determined precisely. Based upon the results obtained by analyzing the thermal diffusivity, it was clearly verified that:

(1) When the thickness of a metal film is smaller than 100 nm, the thermal conductivity is reduced, due to electron scattering at the grain boundaries near the interface.

(2) When the thickness of a metal film becomes hundreds of nanometers, the thermal conductivity is close to that for the bulk material.