Thermal Conductivity and Interfacial Thermal Resistance Measurement of Thermally-Oxidized SiO_2 Films on a Silicon Wafer Using a Thermo-Reflectance Technique

R. Kato[C,S]
Ulvac-Riko Inc., Midoriku, Yokohama, Japan
kato@ulvac-riko.co.jp

I. Hatta
Fukui University of Technology, Gakuen, Fukui, Japan

This paper describes the development of a method to measure the normal-to-the-plane thermal conductivity of a very thin electrically insulating film on a substrate and the interfacial thermal resistance between the film and the substrate.

In this method, a metal film, which is deposited on a thin insulating film, is Joule-heated periodically, and the ac-temperature response at the center of the metal film surface is measured by a thermo-reflectance technique. The one-dimensional thermal conduction equation of the metal/film/substrate system was solved analytically, and a simple and rigorous equation was derived. The present method requires very simple specimen preparation, in comparison to the three-omega method. The present method has been verified by a measurement of thermally-oxidized SiO_2 films (1000 to 20 nm thick) on silicon wafers, including those used for the NIST Round Robin held in 1998. The obtained thermal conductivity lies within that of the VAMAS TWA23 (NIST Round Robin Report) within ~ 10 %.

In this study, we tried to estimate both the interfacial thermal resistance between the gold film and the thermally-oxidized SiO_2 film, and the interfacial thermal resistance between the thermally-oxidized SiO_2 film and the silicon wafer. We measured the apparent thermal resistances of the thermally-oxidized SiO_2 film with a thickness of 20 nm on a silicon wafer with a gold film deposited by two different methods. One method is rf-sputtering, and the other is evaporation. The apparent thermal resistance yielded by the rf-sputtering method is about $24x10^{-9}$ $m^2 \cdot KW^{-1}$ greater than that by the evaporation. This value is almost the same as the apparent interfacial thermal resistance, which has been reported in VAMAS TWA23. These facts indicate that the interfacial thermal resistance between the thermally-oxidized SiO_2 film and the silicon wafer is very small (less than $8x10^{-9}$ $m^2 \cdot KW^{-1}$). Namely, the rf-sputtering seems to produce an interfacial region with a significant thermal resistance (of about $20x10^{-9}$ $m^2 \cdot KW^{-1}$) between the gold film and the thermally-oxidized SiO_2 film, due to the high molecular energy in the sputtering, but the evaporation produces no such interfacial region, and, as a result, the interfacial thermal resistance between the gold film and the thermally-oxidized SiO_2 film is very small (less than $8x10^{-9}$ $m^2 \cdot KW^{-1}$).