Thermoreflectance-Based Submicron Temperature Profiling and Structure Function Analysis for Multilayer Nanostructures

Guesuk Lee[1*]

[1]*Korea Electronics Technology Institute (KETI), Republic of Korea*
E-mail address: gslee@keti.re.kr

Recent advances in nanoscale semiconductor packaging and interconnect technology have led to increasing demands for high-resolution thermal metrology and internal structure analysis techniques. This study proposes an integrated methodology combining thermoreflectance (TR) imaging-based submicron temperature measurement with structure function analysis to extract internal thermal properties of multilayer structures.

Thermoreflectance techniques enable non-contact, optical temperature measurements with spatial resolutions below 1 μm by monitoring changes in the reflectivity of the material surface as a function of temperature. This allows for the capture of localized hotspots and thermal gradients across advanced interposer and redistribution layer (RDL) configurations. However, to fully understand heat conduction paths and material interfaces, temperature profiles alone are insufficient.

To address this, the transient thermal responses acquired from TR imaging were further analyzed using the structure function method. This approach deconvolutes thermal impedance into cumulative thermal resistance and capacitance, enabling the identification of thermal interface layers, defects, and material boundaries in complex 2.5D/3D IC packaging. Experimental results on silicon-based multilayer samples demonstrate that the combined methodology can not only visualize surface temperature profiles but also reconstruct internal thermal architecture with high fidelity.

This hybrid technique is expected to contribute significantly to the thermal design and reliability evaluation of next-generation power and AI semiconductor packages, especially where conventional measurement techniques are limited in resolution or invasiveness.

References

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