

Curvature-Insensitive Methodology for Depth Profilometry in Inhomogeneous Curvilinear Solids using the Thermal-Wave Method

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A generalized similarity normalization methodology for characterizing depth profiles of continuously varying thermophysical properties in curvilinear (cylindrical and spherical) solids is presented. Equivalence of the normalized thermal-wave fields between curved and flat surfaces under certain conditions is investigated based on theoretical models of cylindrical, spherical and flat solids with multi-layered inhomogeneous structures. The principle and the physical mechanism of the elimination of the surface curvature effect from the overall photothermal signal are introduced. The effects of the relative values of radii of curvature of the curvilinear solid, the thickness of the inhomogeneous surface layer and the measurement azimuthal angle on the validity of the technique are discussed in detail. Experimental reconstructions of thermophysical depth profiles of hardened cylindrical steel rods of various diameters are performed based on both curvilinear theory and the equivalent flat surface theory. The reconstructed results are compared and validated.