Optoacoustic Characterization of Anisotropic Silicon Wafers Using Femtosecond-laser-induced Ultrasonic Waves

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The widespread growth of delicate, stacked systems (e.g., micro-electro-mechanical systems in wearable electronics and multi-stacked lithium-ion batteries) has necessitated sophisticated inspection to guarantee system integrity. Driven by the imperative need to nondestructively characterize material properties and evaluate manufacturing defects in semiconductor components, great effort has been made over the past decade, along with the progressive downsizing of semiconductors yet with increased structural complexity. In this on-going research work, we develop a femtosecond-laser-enabled, nondestructive optoacoustic approach to evaluate the material properties of silicon wafers which are of a high degree of anisotropy. The femtosecond-laser-enabled ultrasonics techniques, which are operated in a non-contact manner, offer new possibilities in high-resolution flaw detection, thickness measurement and material characterization, making use of the ultrashort acoustic wavelength of laser-generated ultrasound. A multiphysics model is first established to interpret the interaction between the optical and femtosecond laser-induce high-frequency thermoelastic waves, which gives rise to the perturbation to optical polarization by the thermoelastic waves propagating in anisotropic silicon wafers. Experiment is performed to validate the proposed approach, and results affirm the capability of the approach for material characterization at the micro-scales. The developed approach has paved a new way for selectively acquiring the high-sensitivity optoacoustic wave components for high-definition characterization of opaque, structurally complicated semiconductors.