Fano interference as a tool for non-destructive optical and mechanical characterization of interfaces

Kwan To LAI[1], Pierre-Adrien MANTE[2]

[1]Department of Applied Physics, The Hong Kong Polytechnic University, Hong Kong, [1]Division of Chemical Physics and NanoLund, Lund University, Sweden

Thin films are widely used in numerous industries, from optical coatings on camera lenses to protective coatings on mechanically moving parts. The quality of the interface between a thin film and its substrate is crucial as it dictates the reliability of the thin film deposited. However, the non-destructive characterization of interfaces remains challenging due to their small dimensions and that they are embedded. The traditional methods, like XTEM (Cross-Sectional Transmission Electron Microscopy) can reveal defects, such as voids at the interface. Yet they require sacrificial samples, cost money and time. The development of efficient, in-line and non-destructive interface characterization methods is thus critical. Our research focuses on picosecond ultrasonics, an experimental method based on femtosecond pump-probe spectroscopy, which allows the generation and time-resolved detection of coherent acoustic phonons. This method is widely used for non-destructive characterization and metrology of thin films [1]. In picosecond ultrasonics, an ultrafast laser pulse is absorbed by a sample, which leads to the generation of ultrasounds. The ultrasounds are then detected by measuring the change in intensity of the reflection of a second time-delayed laser pulse. This method can characterize the geometrical, mechanical and optical properties of the thin film, such as film thickness, speed of sound and refractive index. It has also been used to characterize the structure, bonding and roughness of the interface [2]–[4]. Here, we propose a novel method to non-destructively characterize the quality of the interface, more precisely the quality of the bonding. Using the picosecond ultrasonics method, we investigate the signal obtained when phonons propagate at the interface between two media. We predict that, for specific wavelength conditions, photons scattered by phonons in both media can have similar properties and result in the appearance of Fano interferences in the reflectivity of the sample. We show that the interference can be characterized by the mechanical and optical properties of the media forming the interface as well as the quality of the bonding. The method we propose allows to further expand the metrological capacity of picosecond ultrasonics by enabling non-destructive characterization of interfaces.

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