Study of Si/Mo Multilayer Reflector Structures using Picosecond Ultrasonics

Seongtae Jeong, Dept. of Physics, University of California, Berkeley, CA 94720

Nen-wen Pu, and Jeffrey Bokor, Dept. of Electrical Engineering and Computer Sciences, University of California, Berkeley, CA 94720

X-ray multilayer mirror structures can support resonant acoustic excitations (superlattice phonons). These resonances are eigenmodes of the multilayer structure whose frequency depends on the period, material properties and interface properties of the multilayer system [1]. "Picosecond ultrasonics" refers to a technique based on visible femtosecond lasers that can excite and detect these resonances without the need for a transducer to directly contact the structure[2]. It is a pump-and-probe transient reflectivity technique in which the acoustic oscillation is impulsively excited by the absorption of a short "pump" laser pulse and detected as a reflectivity modulation of the "probe" laser beam.

We report the successful application of this technique to a study of Si/Mo EUV multilayer mirrors. Multilayer structures were investigated with various periodicities down to 6.9 nm which is several times shorter than periodic multilayer structures previously studied using picosecond ultrasonics. We confirm that the frequency of the acoustic vibration excited in these structures is linearly proportional to the period of the Si/Mo bilayer. With our present signal to noise ratio, the period of the multilayer structure can be determined with a precision of better than 2%. Significant improvements are possible. Extensive numerical simulations based on physical modeling of generation and propagation of acoustic waves were performed to identify the relevant physical properties of these structures. In particular, through comparison between the experimental data and the numerical simulations, the picosecond ultrasonics technique is found to be a sensitive probe of the interface properties of multilayer structures.

Several variations of this technique are suggested and/or applied to extract physical properties of these multilayer structures. For example, we show that multi-pulse excitation of the acoustic wave is a simple and novel experimental method to separate the purely vibrational response of interest from an interfering electronic response of the system.

Due to the availability of compact and reliable solid-state based femtosecond laser systems, this technique has great potential to be deployed as a compact in-situ monitoring tool of multilayer growth. It is also applicable as a method for inspection of the uniformity of multilayer periodicity across a substrate with spatial resolution better than 10 micron in a raster-scan fashion. Finally, picosecond ultrasonics offers a promising research tool for the general study of physical properties and chemical composition of multilayer structures.

References

[1] H. T. Grahn, H. J. Maris, and J. Tauc, Physical Review B38, 6066 (1988).

[2] H. T. Grahn, H. J. Maris, and J. Tauc, IEEE Journal of Quantum Electronics, QE-25, 2562 (1989).