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Raman scattering as a tool to study structural changes induced in silicon wafers by Intense Femtosecond X-ray Free-Electron Laser pulses

W. Szuszkiewicz[1]*, K. Gas[1], R. Sobierajski[1], D. Klinger[1], J. B. Pełka[1], M. Klepka[1], P. Dłużewski[1], P. Jarocki[1], A. Kamińska[2], T. Balcer[3], J. Chalupský[3], J. Gaudin[3], V. Hájková[3], T. Burian[3], A. J. Gleeson[4], L. Juha[3], H. Sinn[5], K. Tiedtke[6], S. Toleikis[6] and L. Vyšin[3]

[1]*Institute of Physics PAS, Al. Lotników 32/46, 02-668 Warszawa, Pola*nd
[2]*Institute of Physical Chemistry PAS, ul. Kasprzaka 44/52, 01-224, Warszawa, Poland*
[3]*Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Prague 8, Czech Republic*
[4]*CCRLC Daresbury Laboratory, Warrington, Cheshire WA4 4AD, United Kingdom*
[5]*European XFEL, DESY, Notkestr. 85, D-22607 Hamburg, Germany*
[6]*Hasylab, DESY, Notkestr. 85, D-22607 Hamburg, Germany*

Keywords: raman scattering, free-electron laser

*e-mail: szusz@ifpan.edu.pl

The irradiation of solid materials with femtosecond extreme ultraviolet (XUV) pulses extensively studied in recent years offers a number of advantages. First of all it permits a high degree of electronic excitation but with a strongly reduced influence of optical nonlinearities i.e., multiphoton absorption and free-carrier absorption. Moreover, for frequencies range between the plasma frequency and the frequency of the innershell absorption edge, the absorption length for solids varies over orders of magnitude. Therefore, ultrashort XUV pulses allow the preparation of rather well-defined excitation conditions for a variety of excitation depths and optical laser ablation has important practical implications, for example in data storage technology.

The recent development of short wavelength (XUV and X-ray) free-electron lasers, also known as fourth-generation X-ray light sources, enables the study of interaction of ultrashort, femtosecond, intense X-ray pulses with matter. We report on the results of experiments performed at FLASH free-electron laser facility on the interaction of ultrashort high intensity 1012 - 1014 W/cm^2 XUV (λ = 13.5 nm) pulses with solid silicon surfaces at the grazing angle below the critical angle. Silicon is a suitable material for comparisons, broadly studied with femtosecond optical lasers and picoseconds XUV lasers. Moreover it is a standard substrate material for the optical coatings in XUV optics where radiation damage is a key issue. Samples were irradiated by single shots of FLASH radiation. An analysis of possible mechanisms of different, intensity dependent stages of the surface damage requires a knowledge about the spatial distribution of polymorphic crystal structures (amorphous Si, selected pressure-induced phases) introduced by the irradiation. It is demonstrated that Raman scattering technique is an efficient, non-destructive method to detect various Si crystal phases and to estimate the thickness of amorphous layer with an accuracy high enough to make possible further modeling of physical phenomena.

Acknowledgments: We would finally thank the FLASH team at DESY for their continuous support, and we gratefully acknowledge the support for access to FLASH by the European Community under contract RII3-CT-2004-506008 (IA-SFS). This work was partially supported by the Polish National Science Center (Grant No. DEC-2011/03/B/ST3/02453), and by the European Regional Development Fund within the Innovative Economy Operational Programme 2007-2013 No POIG.01.01.02-00-008/08 and No POIG.02.01-00-14-032/08.