The Application of Visible Light Scattering Techniques to Opaque Materials in the Diamond Anvil Cell – Determination of High Pressure Elastic Properties

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Techniques based on the scattering of visible light are particularly useful for determining material elastic properties under high pressure. These include, but are not limited to, Brillouin light scattering (BLS) and impulsive stimulated light scattering (ISLS). BLS measurements have now been made to at least 70 GPa in the DAC [1]. Since it is an inelastic visible light scattering process, BLS allows the direct measurement of the speed of propagation of acoustic waves. The experimental apparatus is modest and relatively inexpensive. However, it is difficult to apply BLS to *opaque* materials in the DAC [2]. This difficulty is largely a consequence of the greatly reduced interaction volume compared with transparent materials. The intensity of scattering from bulk acoustic waves can be orders of magnitude greater than that of scattering from surface acoustic waves (SAW). It some cases the latter signal may be swamped by scattering from the transparent pressure medium or diamond anvils (via multiple different scattering geometries). The technique of impulsive stimulated light scattering (ISLS), while possessing many of the advantages of BLS, offers, in principle, a single, well defined scattering geometry, as well as a very large signal strength, even in the case of metals [3]. ISLS can be considered to be a light-induced ultrasonics process. In contrast to BLS, the acoustic wave is artificially stimulated [4].

With an emphasis on ISLS, I will discuss in detail the practical considerations that must be taken into account when performing these types of measurements. I will also discuss the mathematical formalism that is used to obtain elastic information from surface wave velocities. The presentation will be illustrated with recent applications to relevant materials such as iron and cobalt at pressures in excess of one Mbar [5,6]. In addition, I will describe how surface wave velocities may be used to obtain separately the density, bulk modulus and acoustic velocity of compressed fluids such as helium. Finally, I will mention other potential applications such as the determination of the high-pressure thermal transport properties of metals such as iron.

References

[1] H. Shimizu, H. Tashiro, T. Kume, and S. Sasaki, Phys. Rev. Lett. **86**, 4568-4571 (2001).
[2] J. C. Crowhurst, G. R. Hearne, J. D. Comins, A. G. Every, and P. R. Stoddart, Phys. Rev. B **60**, R14990-R14993 (1999).
[3] J. C. Crowhurst, E. H. Abramson, L. J. Slutsky, J. M. Brown, J. M. Zaug, and M. D. Harrell, Phys. Rev. B **64**, 100103 (2001).
[4] E. H. Abramson, J. M. Brown, and L. J. Slutsky, Annu. Rev. Phys. Chem. **50**, 279 (1999).
[5] J. C. Crowhurst, A. F. Goncharov, J. M. Zaug, J. Phys. C. Cond. Matt. In press, 2004
[6] A. F. Goncharov, J. C. Crowhurst, J. M. Zaug, Phys. Rev. Lett. Accepted, 2004.