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X-ray diffraction from shocked materials: investigating solid-solid phase transitions

JUSTIN WARK, University of Oxford

X-ray diffraction on nanosecond and sub-nanosecond time-scales has proven to be a useful tool in investigating the transient response of shocked crystals. Perhaps the most notable success in this area has been the direct observation of the $\alpha - \epsilon$ transition in laser-shocked single crystals of [001] iron. [1,2] The information extracted from the diffraction patterns has been shown to be in remarkable agreement with multi-million atom molecular dynamics calculations. [3] Having successfully observed the transition in single crystals shocked along the principal axis, several further challenges remain. Amongst these are the exploration of the response of single crystals to shocks propagating along other crystallographic directions (where significantly different response is predicted [4]) the role of pre-existing defects in the time-scale of the elastic/plastic response of the material, and any differences that may occur in polycrystalline compared with single crystal samples.[5] A further challenge will be the development of rapid compression techniques that take samples to off-Hugoniot states (for example so-called quasi-isentropic compression). If such states can be produced in a controlled way, much could potentially be learnt about the state of certain planetary cores, including our own. [1] D.H. Kalantar, J.F. Belak, G.W. Collins, J.D. Colvin, H.M. Davies, J.H. Eggert, T.C. Germann, J. Hawreliak, B.L. Holian, K. Kadau, P.S. Lomdahl, H.E. Lorenzana, M.A. Meyers, K. Rosolankova, M.S. Schneider, J. Sheppard, J.S. Stolken and J.S. Wark, Phys. Rev. Lett., **95** 075502, 2005 [2] J. Hawreliak, J.D. Colvin, J.H.Eggert, D. Kalantar, H.E. Lorenzana, J.S. Stölken, H.M. Davies, T.C. Germann, B.L. Holian, K. Kadau, P.S. Lomdahl, A. Higginbotham, K. Rosolankova, J. Sheppard, and J.S. Wark, Phys. Rev. B, **74**, 184107, 2006 [3] K. Kadau, Timothy C. Germann, Peter S. Lomdahl, and Brad Lee Holian, Science, **296**, 1681, 2002 [4] Kai Kadau, Timothy C. Germann, Peter S. Lomdahl, and Brad Lee Holian, Phys. Rev. B, **72**, 064120, 2005 [5] K. Kadau, T.C. Germann, P.S. Lomdahl, R.C. Albers, R.C. J.S. Wark, A. Higginbotham, and B.L. Holian, Phys. Rev. Lett. Phys. Rev. Lett. **98**, 135701 (2007)