Time Resolved Structural Changes in Phase-Change Optical Media

Japanese National Institute for Advanced Industrial Science & Technology

Paul Fons, Dale L. Brewe, Alexander Kolobov, Junji Tominaga, Edward Stern

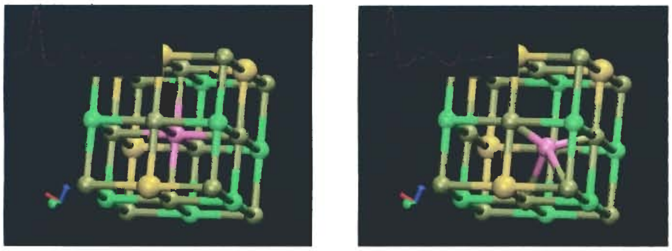
PNC/XOR

Introduction

Optical phase-change media provide a near-ideal solution to the increasing need for digital storage capacity. Re-writable phase-change media are based upon chalcogenide compounds which are reversibly switchable on nanosecond time scales between amorphous and crystalline phases differing significantly in their reflectivity. The amorphous phase is induced by a short, relatively large power focused laser beam and the crystalline phase is restored by a longer, lower-power laser beam. Compounds lying along the pseudobinary tie-line $(GeTe)_x(Sb_2Te_3)_{1-x}$ are in widespread use. Indeed, the commercial media DVD-RAM is based upon $Ge_2Sb_2Te_5$ (x=2/3). While recent work by our group has elucidated the structure of the crystalline and amorphous endpoints (1), little is known about the kinetics of the transformation. Gaining knowledge of the kinetics will provide insight that may be applied to the fabrication of improved media. To this end, we are conducting a pump-probe study of the transformation of $Ge_2Sb_2Te_5$ from the liquid to crystalline/amorphous phases utilizing an x-ray absorption fine structure (XAFS) probe and a 100fs laser pump to obtain measurements with a time quantum determined by the ~100ps x-ray bunch width. Preliminary results have shown that structural changes can be observed on reasonable time scales with good signal to noise ratios.

(1) A V Kolobov, P. Fons, J. Tominaga A. Frenkel, A.L. Ankudinov, and T. Uruga. Understanding the phase-change mechanism of rewritable optical media. Nature Materials, 3.703–708, 10 2004.

Structure of $Ge_2Sb_2Te_5$ in Phase-Change Optical Media



The figures above illustrate the change in the Ge position in crystalline (L) and amorphous (R) $Ge_2Sb_2Te_5$. Ge (pink) undergoes an "umbrella-flip" from an octahedral site to a tetrahedral site in the amorphous material. The tetrahedral site is more tightly bound, and this is seen in a decreased σ^2 (see ref. 1)

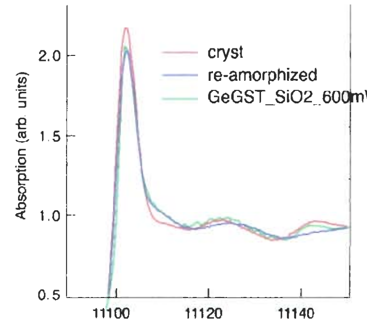
Laser System and Timing Electronics

The PNC/XOR system for time-resolved pump/probe XAFS experiments utilizes a Ti:Sapphire laser system that produces ~100fs pulses at a wavelength of 800nm, with repetition rate equal to the P0 clock rate (272kHz). This allows very high-efficiency XAFS measurements compared to most fs pulsed laser systems, which are limited to rep rates of ~1kHz. The time resolution of the system is primarily determined by the 100ps x-ray bunch width. An APD measures I0 and a fast, large-area plastic scintillator measures x-ray flourescence from the sample. Amplified detector pulses are gated to select the signal from a single bunch, and relative timing between the laser pump pulse and x-ray probe bunch is controlled on a fine time scale by changing the phase of the RF reference used to synchronize the laser output to the ring.

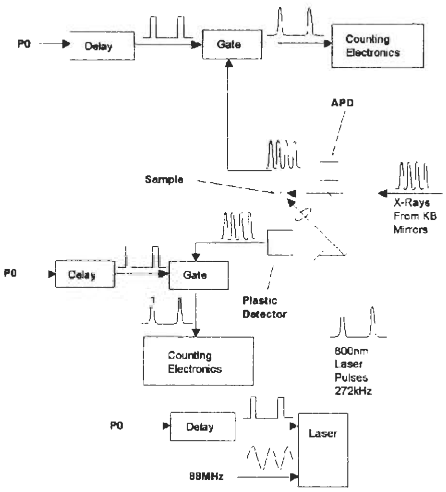
Preliminary Results for Laser-Heated $Ge_2Sb_2Te_5$

Preliminary experiments have been conducted on thin film structures that are similar to those used in actual DVD-RAM media. Results have been obtained in measurements of a film with a 30nm layer of $Ge_2Sb_2Te_5$ on an SiO_2 substrate, with a 30nm MoO cap layer. We found that adequate signal levels were obtained with these samples, but more optimization is required to reduce scattered background further. The figure shows XANES from our sample plotted with XANES from amorphous crystalline material from DVD-RAM media. Our data was taken ~5ns after the laser pulse that heated the film. It can be seen that the white line from our measurements is quite similar to the amorphous material, whereas the first couple of EXAFS oscillations are similar to the crystalline structure. We believe this may be due to an incomplete crystallization of our sample after very fast cooling from the melt state in the first few ns after the laser pulse. In future measurements we will investigate probe times closer to the time of the laser pulse to try and capture the melt state.

The figure shows XANES from our laser-heated film along with XANES from amorphous and crystalline $Ge_2Sb_2Te_5$ films in DVD-RAM media. The XANES of the laser-heated sample shows features common to both structures.



Schematic of the Time Resolved XAFS Apparatus



The illustration shows an overview of the PNC/XOR apparatus for collecting time-resolved XAFS data. The experimental table toward the left holds the sample chamber and positioners, x-ray detectors, and optics for steering and focusing the laser beam onto the sample. The laser system, at the right, includes the Mira 900F and RegA 9000 Ti:Sapphire lasers. The computer in the foreground is used to control the Synchrolock feedback system which locks the lasers to the x-ray ring (Photo taken by R. Fenner for the APS)

Acknowledgments

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