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XAFS Study of structural changes under hydrostatic pressure of Sb-Te phase change alloys

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SuperRENS structures have shown very high carrier-to-noise ratio (CNR) for readout of optical storage patterns well below the far-field optical diffraction limit. In its simplest form the SuperRENS structure consists of a transparent protective cap layer and a phase-change memory alloy layer deposited on a optical memory pattern comprised of pits as small as 30 nm in diameter; layer thickness is typically on the order of a few tens of nanometers. Readout beyond the far-field limit occurs due to transient thermally induced changes in the optical properties of the phase-change layer. Sb-Te alloys have been found to give rise to commercially viable CNR levels. As nearly all of the readout laser light energy is absorbed by the phase change memory layer, calculations show that significant instantaneous pressures on the order of several gigapascal can be induced in the Sb-Te phase-change layer. We have thus carried out structural studies of pressure induced changes in Sb-Te alloys using x-ray absorption spectroscopy using both the Sb and Te K-edges; preliminary results indicate the presence of a pressure-induced phase change at about 7 GPa.

Introduction

As optical media have been to date utilized in the far-field limit, the effective density of information storage has been determined by the diffraction limit given by 2NA/λ, where NA is the numerical aperture of the lens and λ is the light wavelength used for readout. While information density can be increased by decreasing the wavelength of the readout laser, the practical limit has already been reach with the use of a blue laser in the upcoming BluRay optical disk standard; the Blu-Ray standard specifications yield a calculated diffraction limit of approximately 2NA/λ ~ 240 nm.

In the last few years, an alternative recording/readout technique has been developed, the so-called Super-RENS optical disk. By use of thermal lithography in the decomposition of a PtO_x mask layer, recording marks with diameters on the order of tens of nanometers has been realized. Although it might be expected that reading marks much smaller than the far-field diraction limit would prove to be impossible, it has been shown that a special devices structure can achieve this [1]. By placing a phase-change alloy underneath the PtO_x mask layer, marks smaller than the diraction limit can be read out with excellent signal-noise characteristics by utilizing non-linear properties of these alloys under near-field optical excitation induced by a readout laser via marks recorded in the mask PtOx layer. A schematic diagram of a super-RENS structure is shown in Fig.1.

While phase-change materials were first

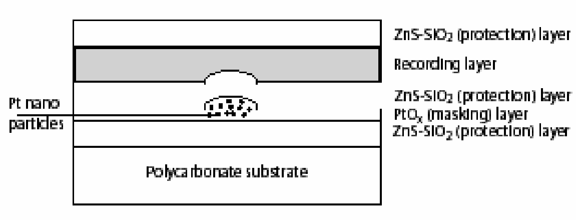

Fig.1 Schematic diagram of typical super-RENS disk structure.

suggested for use as memory elements in the late 1960s, their structural and material properties remained largely unknown. Concomitant with the widespread commercial use of phase-change memory in re-writable disks first initiated by Matsushita in the early 1990s, research activity into the properties of such materials has increased, however much detail still remains to be understood. One common attribute of many phase-change memory alloys is the existence of a metastable structural phase when they are deposited in thin film form. For example, bulk $Ge_2Sb_2Te_5$ is known to form in a trigonal structure with a nine layer stacking sequence, while in contrast, the thin film form has been found to crystallize in a lower density, higher symmetry distorted rocksalt structure [2]. The structure for Sb-Te compounds has also been found to be different in bulk and thin film forms.

Experiment

The readout process in Super-RENS disk structures fabricated using phase-change memory alloys is typically characterized by a sharp increase in readout signal (experimentally determined by the carrier to noise ratio or CNR) with above a critical readout laser power threshold. While it is clear that the readout laser is inducing a non-linear change in optical properties in the phase-change layer, it is not clear what the underlying structural changes giving rise to these changes are. In the Super-RENS multilayer structure, the phase-change material layer is confined above and below by optical transparent layers. As the phasechange layer absorbs essentially all of the non-reflected readout laser power, significant heating effects induced by near-field effects have been predicted to occur [3]. Thermal expansion effects occurring as a result of localized heating are also expected to be significant and lead to instantaneous pressures in the gigapascal range (as the readout process is dynamic and occurs over a time scale of tens to hundreds of nanoseconds, the disk structure is expected to be able to sustain such momentary pressure fluctuations).

To explore the effects of the simultaneous presence of heat and pressure, we have carried out high-pressure, high-temperature x-ray absorption experiments at beamline BL14B1. Powder samples were fabricated from metastable thin films of Sb-Te alloys and mixed with boron nitride powder to attain an absorption cross-section of $\mu \sim 0.8$ at the Te edge. Samples of metastable Sb-Te alloys were enclosed in a graphite tube which served as a heater. The graphite tube was in turn contained in a 7 mm square boron plus epoxy pressure transmitting medium cell. The cell was placed in the tungsten-carbide multiple anvil high pressure stage at BL14XU and changes in local order were measured as a function of pressure at both Sb and Te K edges. While data review is still under way, a preliminary analysis indicates a possible pressure induced phase transition between five and 7 GPa where an additional feature appears in the Fourier transformed χ(R) data at 3.2 Angstroms as can be seen in Fig.2. Further investigations are underway.

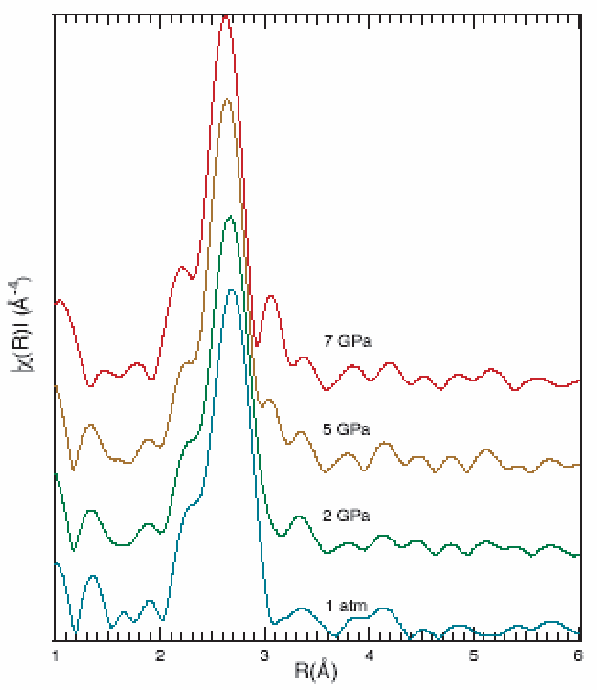

Fig.2 k^3 weighted $|\chi|$ data for Sb absorption centers in a Sb-Te alloy as a function of applied hydrostatic pressure.

References

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