X-ray absorption study of local order changes in the Sb_2Te solid-liquid phase transition

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SuperRENS media constitute a next generation media that circumvents the far-field resolution limit by a about a factor of ten by utilization of an all thin film approach to near-field aperture formation. In a Super- RENS structure, a chalcogenide-based phase-change layer is situated between the data layer and the readout laser beam. Readout laser powers above a critical level induce changes in this layer and give rise to a near- field aperture that allows readout of data bits with spacing about a factor of ten below the far-field resolution limit of λ /2NA. Sb_2Te is a phase-change memory alloy that has been shown to be suitable as a super resolution enhancement media in SuperRENS media. Here we investigate heat-induced changes in local order using x-ray absorption. We also explore the effects of heat-induced pressure on the confined Sb_2Te layer.

The phase change memory alloy Sb_2Te has a strong representation in both current and future optical storage techniques although its properties in metastable thin film, amorphous, and liquid forms are either poorly understood or completely unknown. Sb_2Te serves as the underlying compound of the recording layer in Ag(6)In(4)Sb(60)Te(30) (AIST) based optical memory as manifested by CD-RW/ DVD-RW with Ag and In only playing a minor role in improving the number of rewrite cycles. Sb_2Te is also a leading candidate material for the resolution enhancement layer of the Super- RENS optical disk. A schematic outline of both conventional and SuperRENS disk structures can be seen in Fig. 1.

Whereas in the conventional rewritable DVD structure, a data bit is represented as an amorphous bit amidst a crystalline background, in the SuperRENS structure, an optical near-field is generated by a readout laser via a recording mask layer located above a (Sb_2Te) phase change layer. In response to this near-field, thermally induced changes in the phase-change layer allows readout of recorded data at commerically relevant carrierto- noise ratios (CNR>45 db) using changes in reflected laser intensity. The CNR exhibits a sharp threshold in readout laser power, above which marks of size below the far-field optical diffraction limit exhibit a rapid rise in CNR; to date readout of sub 40 nm marks using a 405 nm laser have been reported, a factor of three below the far-field resolution limit. Single disk storage capacities on the order of a terabyte are planned based upon this technology. The origins of both the sharp threshold in CNR as well as the underlying structural changes occuring in the phase-change layer are unknown; simulations indicate temperatures approaching the melting point are possible. As the phase-change layer absorbs the vast majority of the tightly focused readout laser leaving transparent cladding layers nearly unchanged, elementary thermal expansion calculations show that the equivalent of several GPa of applied stress occur over the tens to hundreds of nanoseconds over which the readout process occurs. X-ray absorption (XAFS) measurements were carried out at both Sb and Te edges to determine the local structure about each atom type. As an important question we wish to address is how local ordering changes near and beyond the melting point of approximately 850 K (and hence how the electronic properties which derive from the local structure change), the ability of XAFS to probe the local structure regardless of long-range order is a necessity. As unlike conventional phase-change media in which data is represented as amorphous regions on a crystalline background, Super-RENS utilizes a (laser-crystallined) crystalline layer to achieve super-resolution readout performance, crystalline Sb_2Te material was used for the experiment. Sb_2Te layers were deposited on silica substrates and were annealed for two hours in a 160 C Nitrogen ambient to crystallize the sample material. Samples were mechanically removed from the silica substrates immediately before the experiment, mixed with the appropriate amount of Boron Nitride and placed into a specially constructed 7 mm high temperature cell for the multianvil high pressure press located at bl14b1. A nominal load of 20 tons was applied to the sample to ensure the sample was well sealed and good electrical conduction could be assumed upon which transmission x-ray absorption data at both the Sb and Te K edges was taken. Both near-edge and extended x-ray absorption measurements were carried out from

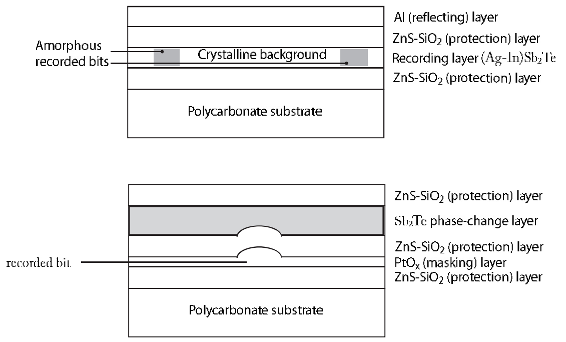

Figure 1 Conventional rewriteable DVD structure (upper) and SuperRENS structure (lower).

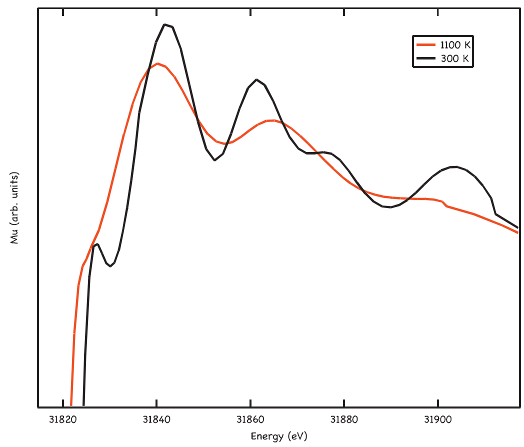

Figure 2 Changes in the near-edge structure at the Te K-edge below 300 K (black) and above 1100 K (red) the melting point of Sb2Te.

room temperature to over 1100 K. Preliminary results suggest there is a decrease in nearest neighbor distance above the melting point in sharp contrast to the conventionally seen lattice expansion with increasing temperature. This fact in conjunction with a large change in the conduction band structure as evidence by a dramatic transformation over the near-edge x-ray absorption spectra above the melting point, strong suggest that there may be an insulator-metal transition in Sb_2Te that occurs at or near the nominal melting point of Sb_2Te. This is further supported by a dramatic change in the near-edge structure at the Te K-edge from just below to above the melting point of Sb_2Te as can be seen in Figure 1. As the near-edge structure is representative of the electronic structure in the conduction band, the sharp broadening of the Te near-edge features is indicative of possible delocalization of bonding states about the Te atom. This is in turn supportive of the possibility of an insulator to metal transition at the melting point. A more detail analysis is under way.

The physics of the readout laser induced near-field optical aperture that allows the readout of data densities an order of magnitude beyond the far-field diffraction limit is at this point poorly understood. It is likely that a deeper understanding of the structural changes occurring in Sb_2Te during readout will lead to more insightful development of yet more optimal SuperRENS materials.

Manuscript status

Analysis of the data is well underway and a manuscript is currently being prepared. It is anticipated that the manuscript will be published within six months.

Keywords

x-ray absorption – the quantum mechanical interference that occurs when a photoelectron emitted by an atom excited at a characteristic energy is partially backscattered from neighboring atoms. As the excited core-electron can only make a transition into unoccupied states, the near-edge structure is indicative of the density of states of the conduction band whereas the extended fine structure can yield information on the types and distances of neighboring atoms located near the absorbing atom.