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XAFS study of pressure-induced changes in Ge-Sb-Te layers used for near-field optical recording below the diffraction limit

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Extended x-ray absorption fine structure measurements have been performed as a function of temperature and pressure at the Ge K-edge in Ge-Sb-Te (GST) in order to elucidate the details of structural changes that may occur in the process of beyond the diffraction limit using optical near-field recording in the SUPER-RENS paradigm. Preliminary results suggest that the local bonding environment about Ge changes from one in which two distinct Ge-Te bond lengths exist (distorted rocksalt structure) to a higher-symmetry (rocksalt-like) bonding environment in which the two Ge-Te bond lengths are equal at a pressure of ~3 GPa beyond which the Ge-Te bond length decreases monotonically with pressure up to 9 GPa.

Te-based alloys, in particular, Ge–Sb-Te (GST) and Ag-In-Sb-Te (AIST) alloys are widely used in production of phase-change media such as re-writable CDs and DVDs. Recently it has been demonstrated that these materials can also be used for near-field optical recording in super-resolution near-field structure (super-RENS) optical discs. The super-RENS technology allows one to go significantly beyond the diffraction limit and record information bits smaller than 100 nanometers with a carrier-to-noise ratio exceeding 40 dB. Use of near-field recording thus makes it possible to achieve a density of optical recording about an order of magnitude higher than in DVDs.

An important difference between presently used phase-change media and super-RENS is that whilst in the former the recorded bits are amorphous marks against crystalline background, in the latter both recorded and non-recorded areas are crystalline. The difference between the recorded and non-recorded areas in super-RENS is that under the recorded bit there is a bubble formed by laser-induced (thermal) decomposition of a Pt-oxide layer that contains Pt nanoparticles, as evidenced by TEM, and oxygen gas [1] (Fig. 1). The non-recorded areas are located above the non-reacted Pt-oxide. During the decomposition of the Pt-oxide, the layer is laser-heated to a temperature of around 600 °C. The neighbouring GST layer is thus also heated and additionally exposed to pressure during the bubble formation. It has been recently shown that temperature plays an important role in super-RENS [2]. Recent X-ray diffraction studies on crystallized GST layers have suggested that laser crystallized GST possesses the

Fig. 1 TEM micrograph of a laser-induced bubble in the PtOx layer of a SuperRens disc.

rocksalt structure [3]. However, our recent EXAFS studies have demonstrated that Ge atom in GST is significantly shifted from the rocksalt position [4]. Significant mode-softening at elevated temperature allows for Ge atoms to vibrate with a large amplitude possibly modifying the crystal structure. We have argued recently that this transformation, which is likely to be of a ferroelectric nature, may be a key point in super dense optical recording [5].

At higher temperatures (the values reported in literature have very large scatter) GST is transformed into stable hexagonal structure.

The important questions are what is the role of GST in near-field optical recording that allows one to go beyond the diffraction limit and achieve a bit size of less than 100 nm with a carrier-to-noise ratio exceeding 40 Db? Is the structure of GST changed upon temperature and pressure? What is this change? Which of the two stimuli is more important? Are GST and AIST the best materials? Or can we suggest other materials with superior parameters?

To investigate the role of temperature and pressure in the recording of nanometer-size bits we have performed extended x-ray absorption fine structure (EXAFS) measurements on GST subjected to the simultaneous action of temperature and pressure at BL14B. EXAFS allows one to selectively probe the local structure around various constituent elements. While, in order to obtain the complete picture, it is interesting to measure changes at all three edges, the allocated time has only allowed us to do two measurements. Based on our previous results that show that the Ge K-edge EXAFS spectrum undergoes the largest change upon crystallization, we chose to measure the Ge K-edge EXAFS. The samples were 3-micron thick GST layers deposited on Kapton. Prior to the experiment, the GST layers were crystallized by annealing for 3 hours at 150°C in an Ar atmosphere. A stack of layers was put into a high-pressure cell using the standard procedure. Measurements were performed at room temperature and at 550°C (somewhat lower than the decomposition temperature of Pt-oxide) using a pressure range up to 10 GPa.

A typical result is shown in the Fig. 2 that shows Fourier transformed data (experiment and fit) for the room-temperature measurement at two different pressures. Fig. 3 shows the variation of the Ge-Te bond length with applied pressure. On can see than in the starting structure there are two different Ge-Te

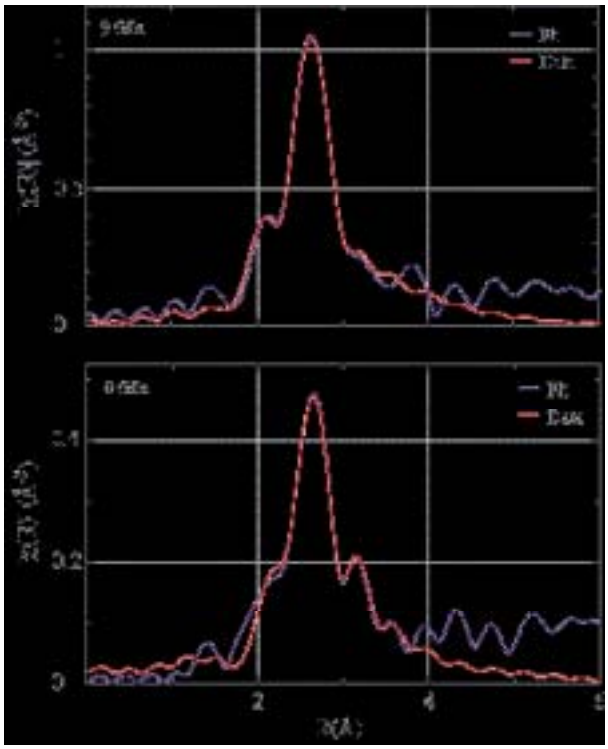

Fig. 2 Fourier transforms of EXAFS data taken at the Ge K-edge for 0 and 9 GPa (blue) and fitted data (red). See text for details.

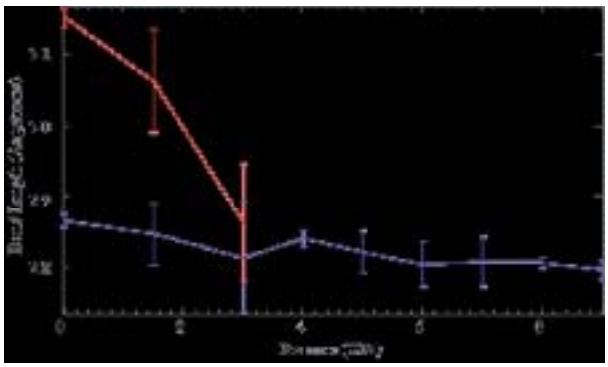

Fig 3. Fitted Ge-Te bond-lengths as a function of applied pressure. The two bond-lengths become equal at ~3 GPa.

distances that merge together at a pressure of ~3 GPa after which the Ge-Te distance decreases monotonically. This result is consistent with our previous suggestion [5] that a ferroelectric transition plays an important role in super dense recording.In the case of high-temperature measurements, the amplitude of the Fourier transform is significantly modified indicating a major structural change. Curve-fitting analysis is currently underw