Detection of Ge XAFS in Ge-Sb-Te optical memory alloys using a high-resolution fluorescence analyzer system

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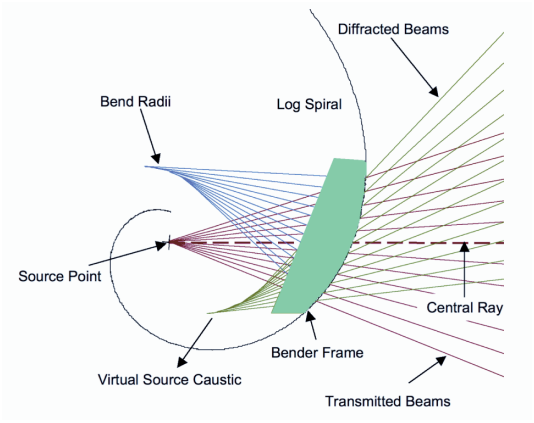
Phase-change alloys based upon chalcogenide compounds are known to exhibit nanosecond scale transitions between the crystalline and amorphous phases and are now in widespread commercial use. Despite their wide use and over thirty-five year history, the properties of the utilized phase transition are only now becoming understood. We recently proposed a structural model (Nature Materials 3(10), 703 (2005)) that describes the local ordering changes occurring in the amorphouscrystalline phase transition based upon our measurements at SPring-8 on the Ge-Sb-Te alloy Ge2Sb2Te5. We believe our model is general and with minor modifications can also describe the local structural changes occurring in other Ge-Sb- Te alloys. Our model is based upon measurements of local structural order using x-ray absorption measurements (XAFS).

Along the GeTe - Sb2Te3 pseudobinary tie-line, there are three different stoichiometric alloys containing all three elemental constituents namely, Ge2Sb2Te5, GeSb2Te4, and GeSb4Te7. As we have already measured the Ge2Sb2Te5 alloys, we have turned our attention to the neighboring GeTe - Sb2Te3 alloy, GeSb2Te4. Due to the larger vacancy concentration of the GeSb2Te4 alloy as well as its reduced Ge content, the effective number of Ge sites probed for equivalent layer thickness is reduced to slightly more than half. This reduction in Ge signal levels has a strong consequence in signal quality when measured by conventional fluorescence techniques. As the as-deposited amorphous phase and the laser-reamorphized phases differ in general, it is necessary to carry out investigations on actual devices structures. With the device structure used Al-Cr (100)/ ZnS - SiO2(30)/ Ge2Sb2Te5(20)/ ZnS - SiO2(130)/ substrate, excitation at the Ge K edge (11.1 keV) leads to the generation of significant background level signal due to the incidental excitation of the relatively abundant number of Zn (K-edge 9.6 keV) sites in the ZnS - SiO2 layers. As energy discriminating detectors such as Ge SSD can distinguish between fluorescent signals only over a limited dynamic range, when the background intensity rises beyond this range, reliable measurements become impossible. We have addressed this problem by employing a log spiral analyzer in the Laue configuration before a conventional Ge SSD.

The analyzer diffracts x-rays of the appropriate

wavelength, according to Braggs law: n λ = 2d sin(θ), where λ is the x-ray wavelength, n (an integer) is the diffraction order, d is the spacing between the diffracting planes of the silicon atoms in the analyzer, and θ is the Bragg angle. X-ray photons of a particular wavelength will only diffract if they are incident at the Bragg angle appropriate to given set of crystal planes. Conversely, through a suitable choice of Bragg angle, only photons of the desired energy are diffracted. For the case of x-rays diverge from a point source, in order to meet the Bragg condition it is necessary to bend the silicon crystal into the shape of a logarithmic spiral. The log-spiral shape has the special property that all the rays that emanate from a point and that are incident onto the log spiral curve have the same angle of incidence. For the current analyzer, this is chosen to be the Bragg angle appropriate to the design energy of 9.6 keV. For the Laue case, as the beam passes through the entire crystal thickness, the analyzer must therefore be thin, otherwise absorption is a problem. For the current detector at 9.9 keV (GeKα), transmission is approximately 50%. A key advantage of using the Laue geometry is that crystal of a given size can cover a large solid angle because the x-rays hit the crystals in a more nearly normal incidence. The Si crystal in the current analyzer was fabricated using an asymmetric cut, i.e. the diffracting planes are not parallel to the crystal surface. As can be seen in the figure a Si crystal bent into the log spiral shape by a bender frame diffracts x-rays from a point source along equal angle outgoing rays. An additional advantage of using a Si crystal in a bent geometry is that the effective rocking curve width increases due to strain by approximately 10-20 times over an perfect Si crystal. This in conjunction with the use of an asymmetric cut geometry allows for a significantly relaxed Bragg condition. By placing an appropriate Sollar slit behind the analyzer, only



Schematic illustration of a log spiral analyzer crystal

x-rays over a limited energy range (FWHM ~ 90 eV) are transmitted with an approximate 300:1 intensity ratio. The wavelength center of the detector is variable over a range of about ~ 2 keV by varying the height of the detector relative to the sample in approximately 10 μm steps. In order to be sure that the detector was properly centered on the correct (Ge) fluorescence line, a multielement Ge detector (SSD) was placed behind the analyzer; the entrance window to the SSD was reduced in effective size using a specially designed lead aperture to allow only x-rays transmitted through the analyzer to reach the SSD. As the underlying principle of a log-spiral detector requires that the x-ray source to be point like, a narrow (sub 100 μm) x-ray beam was used to excite the experime To compensate for the absorption loss in the bent Si crystal, the undulator source at BL37XU was employed and data from GeSb2Te4 device structures were successfully measured.