High-Field $^{121}$Sb NMR in Amorphous Ge$_2$Sb$_2$Te$_x$ ($x = 4, 5, 7$) Thin Films

D.C. Bobela (University of Utah, Physics); T. Su (Colorado School of Mines, Physics); P. C. Taylor (Colorado School of Mines, Physics); A.P. Reyes (NHMFL); P.L. Kuhns (NHMFL)

Introduction

Ge-Sb-Te based amorphous thin films have attracted increasing interest as the materials of choice for phase-change-memory devices. Until now, the local order in these materials has been hotly debated. A particularly important question is how the local bonding symmetry and bond lengths change upon transition between the crystalline and amorphous phases. Using high-field $^{121}$Sb NMR, we studied the quadrupole coupling constant and asymmetry parameter ($\eta$), which characterize the local bonding symmetry and bond lengths around Sn sites in amorphous Ge-Sb-Te films.

Experimental

The experiments were carried out at the NHMFL using a DC resistive magnet (cell 7). Three samples of amorphous Ge$_2$Sb$_2$Te$_x$ ($x=4,5,7$) were studied. The spectra were obtained by sweeping the DC field. At each value of the field, the resonance signal was obtained by a solid-echo pulse sequence to construct a histogram. Details can be found elsewhere [1].

Results and Discussion

Figure 1 shows a typical $^{121}$Sb NMR lineshape. Solid squares represent the lineshape in amorphous Ge$_2$Sb$_2$Te$_5$, and the dashed line represents a simulation. The thick solid line near zero represents the lineshape of the crystalline Ge$_2$Sb$_2$Te$_5$ on the same scale. The linewidth of the amorphous sample is about 30 times that in the crystalline phase. The large quadrupole coupling in the amorphous phase provides evidence of a Te-Sb bond shortening upon transition to the amorphous phase. Spectral simulations suggest that the sites in the amorphous phase, on average, display bonding symmetry characterized by $\eta \approx 1$.

These results indicate that Ge$_2$Sb$_2$Te$_5$ thin films behave differently than typical chalcogenide glasses. In typical chalcogenide glasses, such as As$_2$Se$_3$, the local bonding symmetry and bond lengths at the three-fold coordinated atoms (As) are very similar between the amorphous and crystalline phases, and the disorder is mostly manifested by the distortion of the bonding symmetry of the two-fold coordinated atoms (Se). The results in amorphous Ge$_2$Sb$_2$Te$_3$ strongly contrast this typical picture, and may indicate that the mechanism of transition from the amorphous to the crystalline phase in Ge$_2$Sb$_2$Te$_5$ is qualitatively different from that of the typical chalcogenide glasses.

Conclusions

In conclusion, the high-field $^{121}$Sb NMR has provided a detailed picture of the local bonding symmetry that is otherwise difficult to obtain. These details will facilitate further understanding of the optoelectronic properties in these materials.

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References