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Liquid dynamics of phase-change materials

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Phase-change materials can be rapidly and reversibly switched between the amorphous and crystalline states in a few nanoseconds. They have been successfully employed for non-volatile phase-change memory applications. However, the dynamics of atomic rearrangement processes and their temperature dependence, which govern their ultrafast switching, are not fully understood. Here, using quasi-elastic neutron scattering, we investigate the liquid-state dynamics of a phase-change material Ge15Sb85. With time-of-flight spectroscopy, we measured dynamic structure factors as a function of temperature. The characteristic relaxation times can be extracted at the structure factor maximum, and the mean self-diffusivity of atoms are determined at the low-q range. The relaxation times of Ge15Sb85 are smallest compared with the other phase-change materials such as Ge2Sb2Te5. The mean self-diffusivity of Ge15Sb85 is higher than Te-rich alloys. This indicates that Sb-rich alloys have faster liquid dynamics than Te-rich alloys. This may partially explain the difference in their crystal growth velocities. We show that the relaxation times extracted from neutron scattering are proportional to macroscopic viscosities. A breakdown of Stokes-Einstein relation is observed in all investigated compositions, which can be attributed to the formation of locally favored structures. The latter is likely associated with the liquid-liquid transitions revealed by a recent femtosecond X-ray diffraction study.

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