Model of Ultra-Fast Heating and Crystallisation in Phase-Change Media

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To maintain the increases in writing and erasing data rates in storage technologies involving phase-change media, it is important to investigate the thermal and kinetic requirements that allow successful crystallisation at very high speeds. Although amorphisation from the initial crystalline phase has been shown experimentally[i,ii] and theoretically[iii] to occur within a 1 ns time scale, crystallisation has been difficult to achieve in comparable time scales[i]. Nevertheless, crystallisation at times scales of tens of nanoseconds has been demonstrated by use of appropriate thermal layers[ii,iv].

The authors previously developed an analytical theory that predicted the necessary peak temperature, and hence energy density of the heating source, in a one-dimensional phase-change medium for successful crystallisation during ultra-fast annealing as functions of the kinetic and thermal parameters of the medium[v]. This theory also produced closed-form estimates of the final crystalline mark width and investigated the role of the release of latent heat during crystallisation. For simplicity, this work focused on a one-dimensional medium where the influences of the finite thickness of the phase-change layer and thicknesses and thermal properties of adjacent layers on the heat diffusion process and hence crystallisation kinetics were ignored.

In this work, a two-layer structure consisting of a phase-change layer on top of a thin buffer layer is modelled. The phase-change layer surface is subjected to a Gaussian heat flux distribution with a Dirac Delta temporal profile simulating an ultra-fast heating source. The thermal boundary coefficients at the bottom of the buffer layer allow investigating the use of different substrate materials on the heat diffusion process. The derived expression for the temperature evolution in the phase-change layer is then used in a first order reaction rate equation to study the crystallisation dynamics. The aim of theory is to study the effects of the thicknesses, thermal and kinetic properties of the phase-change and buffer layer on the energy density requirement of the heating source for ultra-fast crystallisation.

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