Solution-processed phase-change memory from molecular telluride inks

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The demand for data storage and processing increases exponentially, projected to reach 175 zettabytes in 2025.[1] With the inability of silicon memory to meet this demand, we must turn to alternative solutions. Phase-change memory (PCM) is among the most mature emerging technologies, offering faster read and write times, non-volatility at elevated temperatures, and multibit analog-type data storage potential, making it particularly suitable for neuromorphic computing and artificial intelligence applications. PCM stores information using the stark electrical resistance contrast between high-resistance amorphous and low-resistance crystalline phases. To write the data, the PCM material is heated locally above the crystallization temperature (SET process); amorphization via melt-quenching erases the data (RESET process).[2] Traditionally, PCM devices are fabricated via sputtering techniques, lithography, lift-off, and etching steps. Solution-phase deposition of chalcogenides at ambient temperature and pressure provides a low-cost and scalable alternative, while simultaneously giving access to a wider range of compositions.[3] Moreover, thin film fabrication from the liquid phase unlocks new geometries of PCM devices (i.e., high-aspect ratio and multilayer arrays)[4], in addition to low-cost high-throughput printing methods.

In this talk, we report the fabrication and performance of the first high-performing liquid-based PCM devices. While reaching state-of-the-art characteristics, our devices hold potential to substantially undercut the price-per-bit, thereby removing the last roadblock towards wide-scale implementation of PCM as the mainstream memory technology. We synthesize a range of PCM material inks by dissolving bulk tellurides in an amine/thiol co-solvent. While this approach has been reported for several technologies,[5–7] it has not yet been demonstrated for state-of-the-art PCM applications. Upon subsequent purification steps, our telluride inks can be deposited to form high-quality thin films with tunable thickness, low surface roughness, and high crystallinity. We highlight the possibility to obtain stoichiometric binary PCM materials (i.e., Sb_2Te_3 or GeTe) and composition-tunable ternary tellurides (i.e., $Ge_2Sb_2Te_5$). Our approach allows for a wide range of tellurides, including ultra-fast Sc-Sb-Te, while ensuring highly homogenous thin films due to mixing on the molecular scale. We then emphasize the added value of liquid-phase engineering through infilling of nanoscale vias, the use of flexible substrates, and multilayer deposition. Finally, we demonstrate the nanofabrication and characterization of tailor-made prototype devices and quantify critical performance metrics, including threshold switching, SET/RESET switching, resistance contrast, power consumption, and cyclability of liquid-engineered PCM devices.

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