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über

Liquid Borne Phase Change Nanomaterials

Abstract:

The demand for data storage and data processing is increasing exponentially and is projected to reach approximately 175 zettabytes (1.75×10^11 terabytes) in 2025. The rapid development of deep learning neural networks and large language models in everyday applications fuels the superexponential demand for data processing, driving the need for alternative memory solutions. Phase-change memory (PCM) is among the most mature emerging memory technologies, offering faster read and write times, non-volatility at elevated temperatures, and multibit analog-type data storage potential.
In this presentation, we leverage the benefits of liquid-based synthesis to access phase-change memory materials in the form of colloidally-stable nanoparticles or molecular inks. We report several approaches, which enable all phase change materials to be prepared in the liquid. For example, our amide-promoted synthesis unlocks a wide library of ternary M-Ge-Te colloids (where M is e.g., Sn, Bi, Pb, Co, Ag, Sb or Cu). [1,2] Nanoscale amalgamation reaction allows reaching the non-equilibrium Sb-rich bimetallic compositions. [3] Finally, thiol-amide co-solvent method brings ternary M-Sb-Te materials to the liquid phase, including classical Ge-Sb-Te and highly performing Sc-Sb-Te phase-change materials. [4] Our solution-based engineering approach offers a generalizable platform for materials development and their rational choice through the studies of structure and dynamics of liquid-borne phase change nanomaterials. [5] For phase-change applications, we enable simpler fabrication and geometrical adaptability of liquid-phase processing, including the infilling of nanoscale vias and the deposition of films on flexible substrates. [1,4] Finally, we demonstrate cyclable and non-volatile prototype memory devices, achieving performance indicators, such as resistance contrast and low reset energy, on par with state-of-the-art sputtered PCM devices. [4]

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References:
[1] D. Kumaar et al., and M. Yarema*. Colloidal Ternary Telluride Quantum Dots for Tunable Phase Change Optics in the Visible and Near-Infrared. ACS Nano 2023, 17, 6985-6997.
[2] O. Yarema et al., and M. Yarema*. Colloidal Phase-Change Materials: Synthesis of Monodisperse GeTe Nanoparticles and Quantification of Their Size-Dependent Crystallization. Chem. Mater. 2018, 30, 6134-6143.
[3] J. Clarysse et al., and M. Yarema*. Size- and Composition-Controlled Intermetallic Nanocrystals via Amalgamation Seeded Growth. Sci. Adv. 2021, 7, eabg1934.
[4] F. M. Schenk et al., and M. Yarema*. Phase-Change Memory from Molecular Tellurides (submitted).
[5] S. Wintersteller et al., and M. Yarema*. Unravelling the Amorphous Structure, Nanoscale Effects, and Crystallization Mechanism of GeTe Phase Change Memory Material. Nature Communications 2023 (under revisions, preprint available).

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