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Thinking like a chemist or beekeeper

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LETTERS

More on phase-change materials for data storage

The piece by Ashley Smart on page 16 of the January 2018 issue of PHYSICS TODAY highlights the ongoing effort to develop rapidly switchable phase-change materials for computer memory and storage. Our work at IBM Research in the early 1980s helped jump-start that effort: It demonstrated for the first time fast crystallization and thermally stable data storage in a reversible phase-change material and clarified the underlying physics.[1]

The key to short crystallization times was picking materials that do not require phase separation and associated diffusion to crystallize. The material must also have a glass transition temperature high enough to guarantee stability of the amorphous phase, into which the data are recorded. And it must be put into a properly designed thermal structure so that heat pulses of different duration can alternatively crystallize and amorphize it.

We demonstrated high-speed crystallization with non-phase-separating compounds such as germanium telluride and antimony telluride. We were aware of materials—pure aluminum, for instance—that crystallize so fast that they could not be thermally quenched to an amorphous phase. In conventional thin-film structures, GeTe suffered the same problem. Building it into a higher-cooling-rate structure, however, increased the quench rate and made amorphization possible. We also understood that amorphous GeTe, with a structure similar to a close-packed liquid, would often be kinetically disposed to form a metastable face-centered cubic crystalline phase. That extended the range of workable compositions beyond those suggested by an (equilibrium) phase diagram.

We shared our understanding with researchers at Matsushita Electric Industrial (now Panasonic), who then expanded the set of fast-crystallizing materials to include the GeSbTe-type materials. The smaller bit geometries associated with modern nonvolatile memories allow for higher quench rates and thus enable faster-crystallizing materials to be considered.

The latest research from China, as highlighted by Smart, is notable in introducing "rational design," such as the doping of SbTe with scandium to seed heterogeneous nucleation. It raises an interesting question: How would the picture change if Sc were deposited in a discontinuous layer rather than dispersed throughout the SbTe film?

Reference

1. M. Chen, K. A. Rubin, R. W. Barton, *Appl. Phys. Lett.* **49**, 502 (1986).

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[Editors' note: We invited Feng Rao and Wei Zhang, authors of work discussed in Ashley Smart's Search story, to write a brief reply.]

▶ **Rao and Zhang reply:** We are happy to answer the question posed by Kurt Rubin and Martin Chen in their last paragraph. In our work,[1] scandium atoms were deposited randomly throughout the antimony telluride (Sb_2Te_3) thin film to serve as robust crystalline precursors for speeding up the intrinsic incubation of stable nuclei. If Sc atoms were deposited into discontinuous layers, potentially forming Sc_2Te_3, those layers may serve as a robust two-dimensional template to trigger rapid crystal growth. Such a scenario may be increasingly important as memory cells get miniaturized to achieve higher storage density. If ultrafast nucleation can be properly combined with rapid crystal growth via a stable 2D template, even faster memory writing speed can be expected. More research efforts should be invested in that exciting direction.

Reference

1. F. Rao et al., *Science* **358**, 1423 (2017).

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Thinking like a chemist or beekeeper

I enjoyed the general content and applaud the overall message of Charles Day's column "Thinking like a biologist" (PHYSICS TODAY, April 2018, page 8). In examining biophysical systems, physicists are often biased toward parameters they can readily alter, such as temperature and pressure, and may overlook parameters that they have less familiarity with or control over, such as chemical composition.

An error slipped into the discussion on fats, however: Liquid fats, like many vegetable oils, tend to have more double bonds than solid fats, like tallow. Indeed, small chemical changes can have big physical effects. For example, the replacement of one single carbon bond with a double carbon bond can drop the melting transition temperature of a hydrocarbon-based compound by more than 50 °C. Likewise, even the type of double bond—*cis* or *trans*—has dramatic physical and biophysical effects.

Furthermore, at the risk of not minding my own beeswax, I'll be bold enough to hazard a possible explanation for the different behaviors of the beeswaxes obtained from different sources. The information that the usual source was sold out and yet the other source was not only available but cheaper is perhaps suggestive. Beeswax is generally much more costly than paraffin; it turns out that adulteration of beeswax with paraffin is common and generally seems to result in a lower melting temperature.[1]

Reference

1. L. Svečnjak et al., *J. Apic. Sci.* **59**(2), 37 (2015).

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Correction

October 2018, page 38—The red stepped line in figure 1 is a fit to the astrophysical neutrino flux, not the atmospheric component. PT