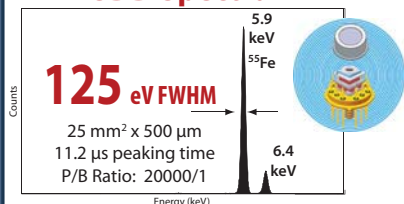


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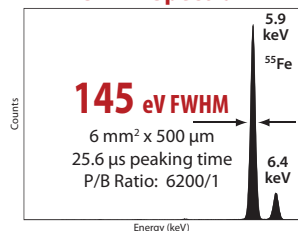
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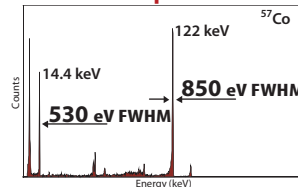
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and Spectrum Experiment at Oak Ridge National Laboratory, the Detector of Anti-Neutrino based on Solid Scintillator project at the Kalinin Nuclear Power Plant in Russia, and the Stereo experiment at the Institut Laue-Langevin in France—aim to suss out the reactor anti-neutrino anomaly. At Fermilab, the Short-Baseline Neutrino Program to search for sterile neutrinos will have a complement of three detectors—Imaging Cosmic and Rare Underground Signals detector, MicroBooNE, and the Short-Baseline Near Detector—to monitor an accelerator neutrino source (see PHYSICS TODAY,

July 2015, page 23). MicroBooNE began collecting data last October as a stand-alone experiment. “There’s a big global effort to do future experiments,” says Kayser. “This is an experimental question. And we really need experiments to settle the issue.”

Sung Chang

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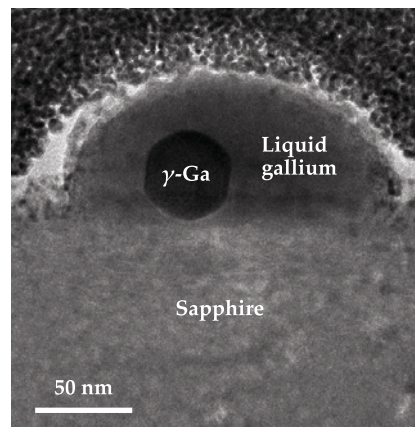
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A droplet that won't freeze harbors a crystal that won't melt

The gallium nanodroplet's anomalous phase behavior is a new twist on the maxim “small is different.”

To the casual observer, the tiny crystal of gallium visible in the adjacent figure might seem remarkable primarily for its scale, just 40 nm—roughly 100 atoms—in diameter. But for the University of Western Australia's Alexandra Suvorova, who took the transmission electron microscope (TEM) image, the bigger surprise was that the speck of frozen Ga was there at all. According to the metal's phase diagram, the observed crystalline structure—a hexagonally packed arrangement known as the γ phase—occurs only at temperatures below 236 K, far cooler than the ambient temperature at which the image was taken.

Moreover, the diminutive lump of solid is enveloped in a shell of molten Ga, which seems to fly in the face of conventional rules of thermodynamics. Those rules stipulate that at a fixed pressure, a pure substance's liquid and solid phases can coexist at precisely one temperature, the melting point. For Ga at atmospheric pressure, that temperature is around 303 K, several kelvin hotter than Suvorova's droplet. Even when the droplet is chilled below 200 K or heated to 800 K, it retains its two-phase character. The finding,¹ newly reported by a team led by Maria Losurdo (CNR-NANOTEC, Bari, Italy) and April Brown (Duke University), has theorists scratching their heads.



A BURIED GEM. At the core of the molten gallium nanodroplet shown here, the metal adopts a crystalline form known as the γ phase. The liquid and solid phases coexist over a temperature range of more than 600 K. Interactions between the droplet and the underlying sapphire substrate are thought to cause the anomalous behavior. (Adapted from ref. 1.)

Nicola Gaston, a physicist at the University of Auckland, has been studying metal nanoparticles for more than a decade and says she's never seen anything quite like it. Experiments have generated indirect evidence of coexistence, she says, “but they've never produced anything so clear as this.”

Gaston adds that the earlier experi-

ments tended to suggest solid–liquid coexistence in small temperature windows of “maybe 5 K or 10 K.” Those observations fit with the predictions of numerical models that account for finite-size effects that become significant at nanometer length scales.² But the models can’t explain the 600 K coexistence range observed for the Ga nanodroplets.

Losurdo and her colleagues suspect that the unusual behavior is related to the droplet’s interactions with the underlying sapphire support. Because sapphire’s crystalline lattice nearly matches that of γ -Ga in size and shape, the partial crystallization of Ga at the sapphire surface would relieve interfacial stress and reduce the droplet’s energy—even at temperatures ordinarily too high for the solid to exist. At the droplet’s outer surface, the high energetic cost of forming a gas–solid interface would prevent the liquid shell from completely freezing.

When collaborating theorist Kurt Hingerl (Johannes Kepler University Linz) modified standard energy-balance equations to include those surface effects, he got results consistent with the group’s working hypothesis. Follow-up experiments provided yet more supporting evidence: Solid cores failed to materialize in Ga droplets deposited on amorphous glass instead of sapphire. Still, Hingerl acknowledges, the team’s theoretical model remains incomplete. It doesn’t explain, for instance, why only a

small fraction of the Ga along the sapphire boundary crystallizes, despite energy balances that indicate an overwhelming preference for the solid–solid interface.

As Gaston sees it, however, the TEM images alone are reason enough for excitement. Interfaces buried in the interiors of metal nanoparticles are both notoriously difficult and important to study. Understanding how they form and evolve is crucial to deploying the particles in phase-change memories, nanoplasmonics, and other applications. (For more on metal nanoparticles, see *PHYSICS TODAY*, June 2007, page 26.) Losurdo and her colleagues aren’t the first group to use TEM to tackle that problem, but they were able to achieve exceptional resolution—high enough, for example, to confirm theoretical predictions that Ga’s solid–liquid interfaces are not atomically abrupt but roughly four atoms thick.

“The quality of the experimental images is fantastic,” comments Gaston. “Soon we’ll be able to combine these kinds of experiments with theory to start sketching out phase diagrams at the nanoscale.”

Ashley G. Smart

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Solid-state NMR resolves protein structures—no deuteration required

Spinning the samples at extraordinarily high frequency is key to untangling the biomolecules’ complicated spectra.

A murder-mystery villain, if she were resourceful and patient enough, could bring about her victim’s demise by replacing all his drinking water with heavy, or deuterated, water. That’s because D_2O , although superficially similar to H_2O , behaves differently enough in enzymatic reactions that in large quantities it’s detrimental to living tissues. Rats die within a week when given nothing but D_2O to drink.

Escherichia coli bacteria, on the other

hand, can survive in D_2O . That’s fortunate for protein researchers, who genetically engineer the bacteria to manufacture deuterated proteins to use in nuclear magnetic resonance spectroscopy: Replacing most of a protein’s abundant magnetic hydrogen-1 atoms with deuterium, which is invisible to NMR tuned to 1H , helps to simplify the spectrum. To ensure uniform isotopic substitution, researchers first use bacteria to create entirely deuterated proteins, then back-substitute some



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