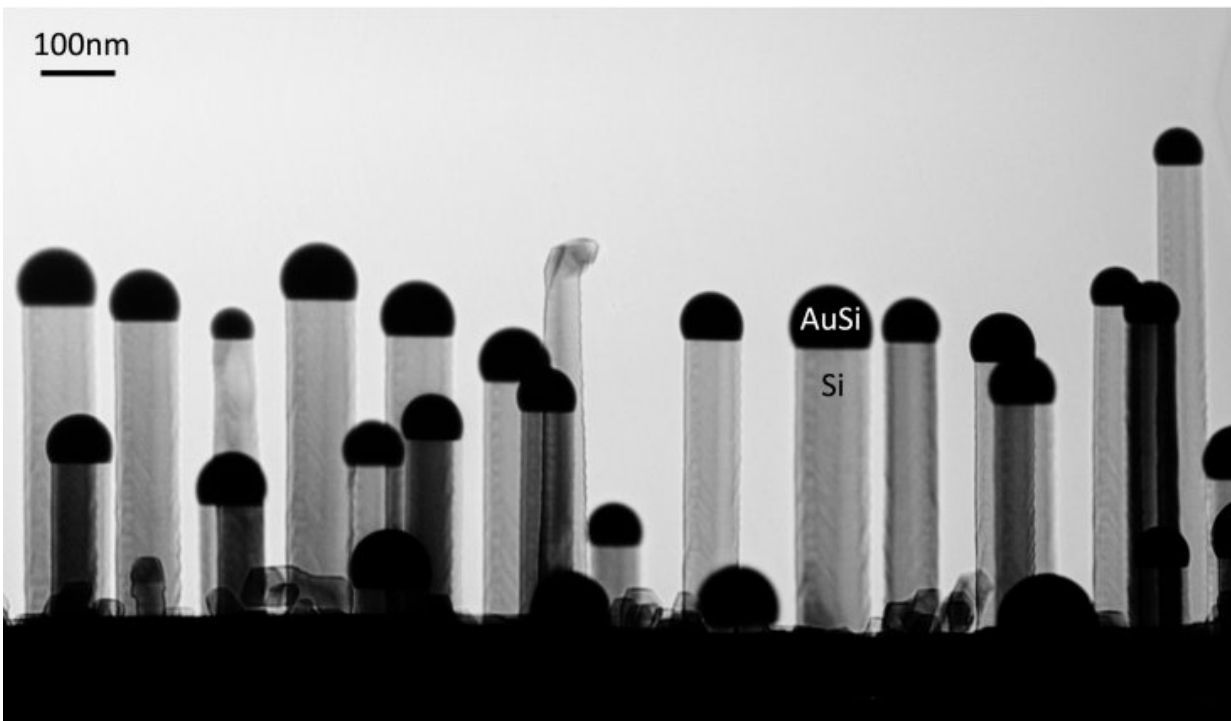


Frances Ross discusses witnessing nanostructure formation

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This image shows silicon nanowires grown in the microscope. The dark areas are the catalysts — liquid droplets of a gold-silicon compound — that cause the nanowires to grow. Credit: Frances Ross and *Reports on Progress in Physics* / IOP Publishing.

Professor Frances Ross joined the MIT Department of Materials Science and Engineering this fall after a career of developing techniques that

probe materials reactions while they take place. Formerly with the IBM Thomas J. Watson Research Center in Yorktown Heights, New York, Ross brings to MIT her expertise in applying transmission electron microscopy to understand how nanostructures form in real time and using the data from such movies to develop new structures and growth pathways.

Q: What insights do we gain from observing nanoscale crystal structures forming in real-time that were missed when observation was limited to analyzing structures only after their formation?

A: Recording a movie of something growing, rather than images before and after growth, has many exciting advantages. The movie gives us a continuous view of a process, which shows the full evolution. This can include detailed information like the growth rate of an individual nanocrystal. Recording a continuous view makes it easier to catch a rapid nucleation event or a really short-lived intermediate shape, which may often be quite unexpected. The movie also gives us a window into the behavior of [materials](#) under real processing conditions, avoiding the changes that usually occur when you stop growth to get ready for post-growth analysis. And finally, it is possible to grow a single object then measure its properties, such as the electrical conductivity of one nanowire or the melting point of a nanocrystal. Of course obtaining such information involves greater experimental complexity, but the results make this extra effort worthwhile, and we really enjoy designing and carrying out these experiments.

Q: What will your role be in moving these techniques forward through the new MIT.nano facility?

A: MIT.nano has some very quiet rooms downstairs. The rooms are designed to have a stable temperature and minimize vibrations and electromagnetic fields from the surroundings, including the nearby T line [subway]. Our plan is to use one of these rooms for a unique new electron microscope. It will be designed for growth experiments that involve [two-dimensional materials](#): not just the famous graphene but others as well. We plan to study growth reactions where "conventional" (three-dimensional) nanocrystals grow on two-dimensional materials—a necessary step in making full use of the interesting new opportunities offered by two-dimensional materials. Growth reactions involving two-dimensional materials are difficult to study using our existing equipment because the materials are damaged by the electrons used for imaging. The new microscope will use lower voltage electrons and will have a high vacuum for precise control of the environment and capabilities for carrying out growth and other processes using reactive gases. This microscope will benefit growth studies in many other materials as well. But not every experiment requires such state-of-the-art equipment, and we also plan to develop new capabilities, particularly for looking at reactions in liquids, in the microscopes that are already operating in Building 13.

Q: What technologies will most immediately benefit through enhanced observation of nanoscale structure formation?

A: I think that any new way of looking at a material or a process tends to impact a much broader area than you at first imagine. It has been very exciting to see how many areas have made use of the opportunities presented by these types of growth experiment. Growth processes in liquids have already probed catalysts in action, biomineralization, fluid physics (such as nanoscale bubbles), corrosion, and materials for rechargeable batteries. Some biological, geological, or atmospheric

processes will also eventually benefit from this type of microscopy. Growth reactions involving gases are particularly well suited to addressing questions in catalysis (again), thin films and coatings, processing for microelectronics, structures used in solid-state lighting, and a variety of other technology areas. Our approach has been to choose relatively simple materials that have useful applications—silicon, germanium, copper—but then use the experiments to probe the basic physics underlying the materials' reaction and see how that might teach us how to build more complex structures. The simpler and more general the model is that explains our observations, the happier we are.

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