

G-Line

WATCHING ATOMS ARRANGE THEMSELVES

Vivid Properties

Imagine taking a handful of ceramic tiles of various colors and throwing them against a wall. After the dust settles, to your utter amazement you see that the tiles are organized into a beautiful, flawless mosaic design. This scene is unimaginable in everyday life, but it is an accurate microscopic description of a common technique used to grow nearly defect-free crystals of complex materials that exhibit striking physical properties, such as high-temperature superconductivity and colossal magnetoresistance.

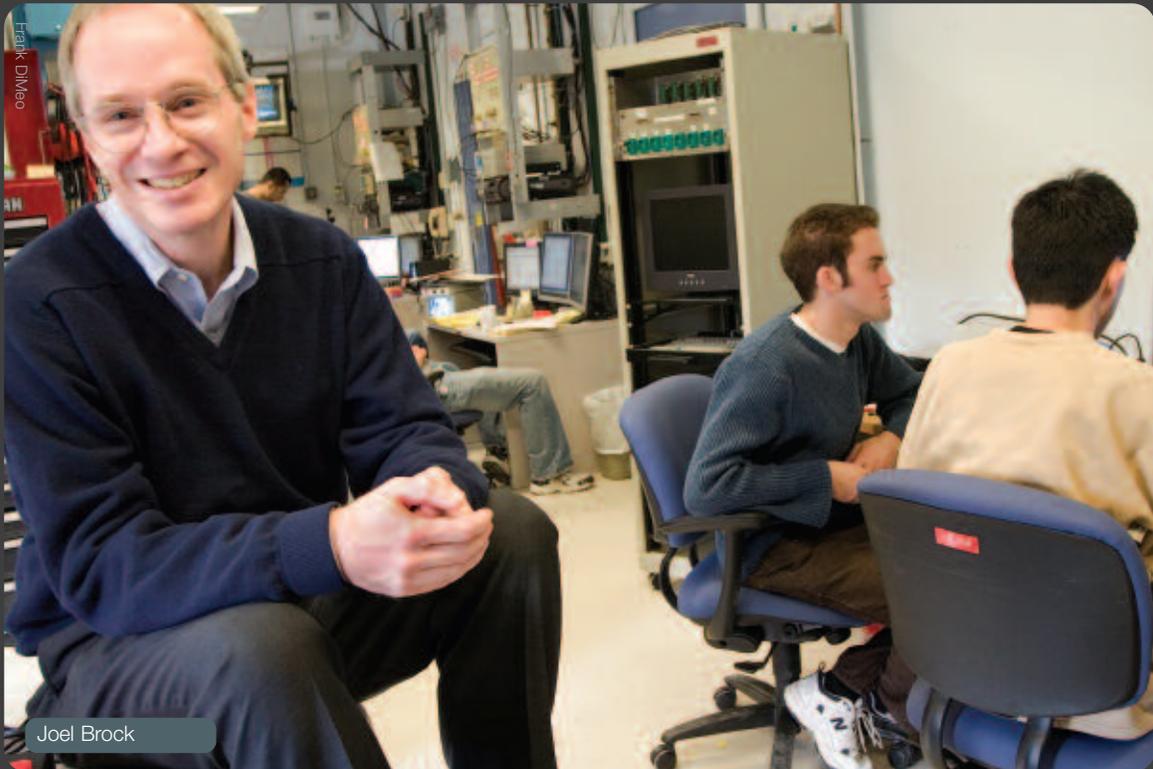
To Grow Perfect Crystals of Unusual Materials

Because a high power laser beam is used to vaporize material within a target, this growth technique is called pulsed laser deposition (PLD). The resulting “plume” of material is directed onto a substrate and forms—under the correct conditions—a perfect crystal. PLD is frequently the technique of choice for growing thin films of materials consisting of several different atomic species, because the chemical composition of the deposited film faithfully preserves the chemical composition of the original target. My research peeks behind the curtain to

study the microscopic mechanisms by which the atoms (that certainly land at random locations) arrange themselves into a nearly error-free pattern.

To do this, researchers need to be able to make measurements that enable them to “watch” the atoms rearrange themselves. The wavelength of x-rays and their ability to pass through material without being absorbed (think of a chest x-ray) make them ideally suited for structural studies on atomic-length scales. Indeed, most of what is known about the atomic scale structure of materials is based on x-ray measurements. The main challenge is to produce a beam of x-rays with sufficient intensity to obtain a measurable signal from a single atomic layer or less of deposited material. CHESS’s G-line facility was specifically designed to produce the intense x-ray beams needed to perform this type of growth study.

As with visible light, a very smooth surface reflects x-rays more perfectly than a rough surface, which scatters light in all directions. During PLD, as a pulse of material lands on the smooth surface, the intensity of the reflected x-ray beam instantly responds to the change in the surface roughness and



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Pulsed laser deposition growth technique:
A high power laser beam is used to vaporize material within a target. The resulting “plume” of material is directed onto a substrate and forms a perfect crystal.



Plume of $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ depositing onto a SrTiO_3 substrate in the pulsed laser deposition chamber.

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For more information:



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then relaxes as the material diffuses, smoothing the surface. By carefully measuring both the instantaneous jump and the ensuing relaxation of the x-ray signal, researchers are able to infer how the atomic structure of the deposited film evolves both during the initial collision and during the subsequent relaxation. It turns out that the initial collision plays an important role in keeping the surface smooth. Basically, you need to throw the tiles at the wall hard enough to squeeze the tiles into place, but not so hard that they cause damage. It also turns out that “soft” objects rather than “hard” objects are the best ones to throw. Think of how a hard, dry sponge bounces, but a soft, wet sponge sticks in place

**Advanced Training:
The Fleet-and-Dale Approach**

While the G-line facility is optimized for time-resolved x-ray studies of evolving materials, its goals are still greater. Education is an essential part of its mission. The G-line facility is consequently dedicated to serving the research interests of Cornell research groups by providing an environment where students at all levels can receive advanced training and obtain in-depth experience in designing, building, operating, and using synchrotron x-ray technology.

BECAUSE A HIGH POWER LASER BEAM IS USED TO VAPORIZE MATERIAL WITHIN A TARGET, THIS GROWTH TECHNIQUE IS CALLED PULSED LASER DEPOSITION (PLD).

G-line’s PLD facility is an excellent example. The PLD system was designed and constructed by two graduate students, Aaron Fleet (Applied Physics, now at MIT, Lincoln Lab) and Darren Dale (Materials Science, now a CHESS scientist). Fleet and Dale were also major participants in the construction and commissioning of the entire G-line facility. They then used their equipment and the beamlines to perform their Ph.D. research.

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