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Material for Future Low-Power Electronics

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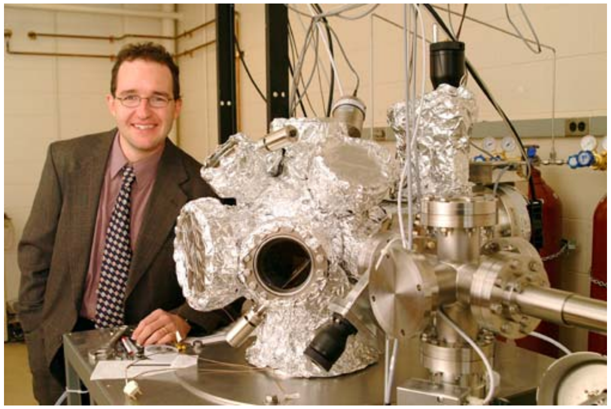
Outcome: Researchers at Rensselaer Polytechnic Institute have created a material that is at the same time magnetic and a semiconductor.

Impact: Such a material will potentially enable electronic devices that use up to 1000 times less power, saving electric power used by computers and dramatically increasing the battery life-time of cell phones.

Explanation: Industrially made "chromium nitride" conducts electricity like a metal. However, if chromium nitride is made extremely pure, with all atoms arranged on a perfect array, it becomes a magnetic semiconductor. Such a material is required to build "spintronic" devices. Spintronics is a future (beyond 2020) technology that uses the spin of electrons to transport information. It may replace electronics since it uses much less power and may also enable safer communication.

Professor Daniel Gall, of Rensselaer's Department of Materials Science and Engineering and recipient of an NSF Faculty Early Career Development (CAREER) award, led the team, which developed the new features of chromium nitride by using atomic shadowing and surface diffusion techniques during physical vapor deposition.



Prof. Gall next to a ultra-high vacuum deposition system used to create high quality chromium nitride. (courtesy of Rensselaer Polytechnic Institute)

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Temperature Predicts Morphology & Porosity

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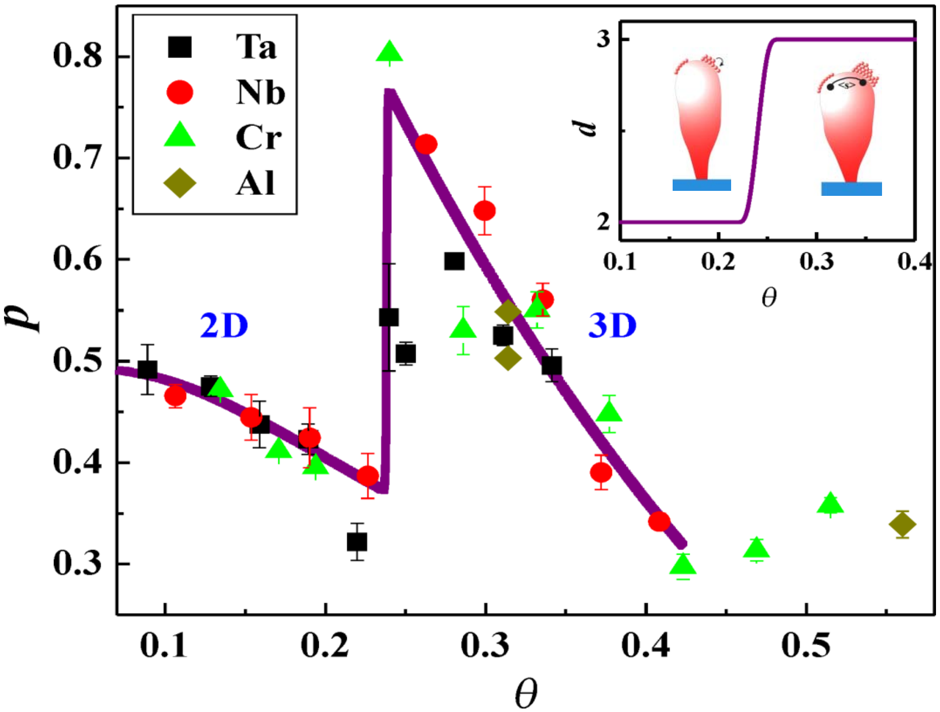
Thin films and nanostructures deposited by physical vapor deposition exhibit various shapes and roughness features. The development of these structures is controlled by two competing atomistic effects: (1) atomic shadowing and (2) surface diffusion. Graduate student Srijit Mukherjee has measured ~30,000 nanostructure widths and found that they can be described by non-linear scaling and a temperature dependent growth exponent. Surprisingly, this result depends only on the melting point and not on any other material property. Therefore, this finding can be used to predict morphology and porosity of uninvestigated deposited layers, as widely used in microelectronics and optical coatings for energy applications.



The nanostructure growth exponent p varies with temperature θ, exhibiting the same 2D to 3D discontinuity for all investigated materials.
(courtesy of D. Gall)

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Materials Machine

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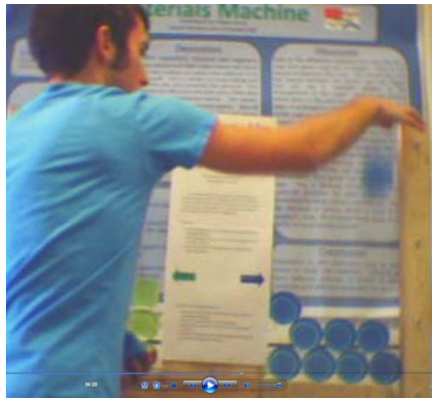

Screen shots of a movie where undergraduate student Adam Bross explains Materials Science concepts to children grades 3-7. Different atoms (green and blue) form different crystal structures. (courtesy of D. Gall)

An integrated education and outreach effort of this project includes the design and construction of a “Materials Machine,” which is a thin film deposition simulator that uses balls or discs to illustrate the formation of a crystalline material by “simply dropping atoms onto a substrate.” The simulator has been developed and sequentially improved over multiple years by undergraduate students: Heather Bowman, Erika Schnitzler, and Adam Bross. It has been used as demonstration tool in the class room.

The latest efforts include a movie geared towards children in grades 3-7, that can be downloaded on the internet. Also, a related website describes the “machine” and basic concepts of materials science, including “atoms”, “bonding”, “structure”.

http://www.rpi.edu/~galld/materials_machine/materials_machine.htm

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