Steve Durbin
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For a researcher at a globally engaged university, international collaboration comes naturally. When Dr. Steve Durbin, professor and chair of the Department of Electrical and Computer Engineering, recently received a grant from the National Science Foundation to explore the synthesis and characterization of a new semiconductor (ZnSnN2) comprised solely of earth-abundant elements, he and his students embarked on this project with partners in the United Kingdom, Finland, and New Zealand, as well as Colorado, Michigan and Florida.

The material is formed using a sophisticated ultra-high vacuum technique known as molecular beam epitaxy (or “MBE”). MBE uses thermal evaporation to create what are called “thin films” — single crystals whose thickness may range from a few atoms to about 1/100th of the diameter of a human hair.

Durbin came to WMU in July 2013 with “several decades” of experience as an engineering professor and researcher. He initially planned to become a computer sciences engineer, but while working his way through school doing odd jobs he ended up working in an electrical engineering lab. His main responsibility was moving liquid nitrogen between two buildings for an MBE lab. “The MBE I brought to WMU turned out to be in that research lab,” Durbin said. He switched majors and became an undergraduate research assistance to the professor who was using the machine at that time.

Many compounds currently used for devices such as LEDs, solid state lighting elements, and lasers are based on indium and/or gallium, both of which are expensive, and whose long-term supply is a concern. Durbin is experimenting with ZnSnN2 as a potential alternative. Zinc (Zn) and tin (Sn) are much cheaper than either gallium or indium, are abundant in the earth’s crust, and approximately one-third of domestic consumption in the United States comes from reclamation sources, which is not the case with indium and gallium.

The MBE takes a week to achieve the appropriate level of vacuum to grow crystals. Durbin said the process starts with a substrate on which he attempts to grow a single crystal wafer in the pursuit of achieving a perfectly ordered lattice. “No one has achieved that yet,” he said. “Electrons don’t travel far in devices, so you don’t need a big crystal. We can grow layers that are just one atom thick, slowly, in a high purity environment.”

Graphic rendering of expected crystal structure of ZnSnN2. The small atoms are nitrogen. The atoms depicted with stripes are either tin or zinc, in equal numbers. The key issue is whether the zinc and tin atoms are randomly distributed on their lattice sites, or show a periodic arrangement among themselves.
Earlier in his research, Durbin was surprised to discover that growing perfect crystalline structures might not be necessary.

“It turns out that the “band gap energy” – the most critical parameter which characterizes any semiconductor – might be tunable in this material, not by adding other elements as done presently, but instead by “scrambling” the order of zinc and tin atoms in the crystal lattice in a controlled way,” Durbin said. “A perfect match for the sun which reaches earth’s surface is a band gap energy of 1.5 eV. “Randomized” ZnSnN2 has a predicted band gap energy of about 1 eV, whereas “perfectly ordered” ZnSnN2 should have a value of 2 eV. Half-way between, then, would be ideal for a solar cell. This is the main focus of our research at the moment.”

Collaborators on the project include researchers at Florida A&M University, the University of Liverpool (UK), the University of Michigan, University College London (UK), the National Renewable Energy Laboratory, and the University of Canterbury.

“The nature of our work leads to collaboration,” he said. “I am preparing materials other researchers are interested in looking at and measuring in other ways. It’s difficult to afford to have all pertinent research equipment and techniques in one institution. My collaborators are people looking at similar kinds of problems with different instruments.”

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Dr. Steve Durbin and research assistants Nathaniel Feldburg (far left) and Brian Durant prepare to grow crystals in the molecular beam epitaxy machine.