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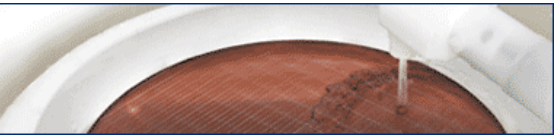
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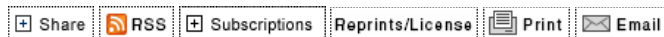
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Beating the Heat in Power Electronics

Sally Cole Johnson, Contributing Editor -- Semiconductor International, 3/1/2007

Power electronics packages that can manage high-current density, high temperatures and high-temperature gradients in some of the harshest-imaginable operating conditions — such as those found on warships and military aircraft — are being developed for the U.S. Navy by the State University of New York at Buffalo's [Electronic Packaging Laboratory](#). And there may soon be far-reaching non-military applications as well.



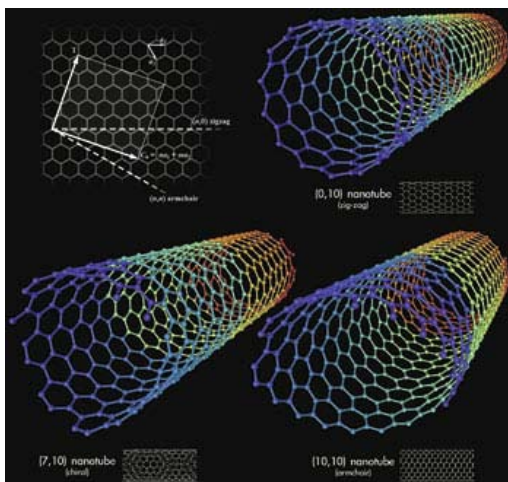
As part of our power electronics packaging efforts for the Navy, we've been designing and testing micro- and nano-scale electronics packaging test vehicles that maintain reliability under extremely harsh conditions resulting from high-current density, high-power, high-temperature and vibration loads," explained Cemal Basaran, director of the lab. "We're interested in running large power electronics in a very small scale, and in a much more reliable way."

Two big challenges facing Basaran and UB engineers working on the project are current density and temperature gradient. "If materials behaved the way we expected at high-current density, we could design devices smaller, and have no problem making them smaller," Basaran said. "However, when you increase current density too much by making the cross-section smaller, instead of just the electrons moving in the conductor, the 'windforce' of the moving electrons increases so much that they start sucking up all the atoms. Then the atoms begin moving with the electrons, and we essentially see mass migration of the solid from one end to the other. This causes a void in the cathode side and a mass accumulation in the anode side. After a little while, there is such little mass remaining on the cathode side that the current density, also known as current crowding, becomes so high that the metal just melts and the device fails."

Unfortunately, at small scale, metals don't behave well or accommodate running large-current density.

So Basaran and colleagues are working with metals and changing their diffusion properties to make them handle high-current density — essentially making them solid solution alloys. "We're alloying them in such a way that we can use different solid solutions to slow the diffusion process. It's a method to make existing metal technology do a better job of soldering high-temperature materials and develop better solutions to slow the degradation," Basaran said.

Another front Basaran's lab is working on theorizes that metals have reached their limits, so they've turned their attention to a new generation of materials: carbon nanotubes ([Figure](#)). "The biggest problem with metals is that when you run a current through them, Joule heating occurs, which causes problems in all electronics. The most desirable solution, especially in military applications, is to not generate heat when you run current through a system," Basaran said. "Single-walled carbon nanotubes show potential to be an excellent material in this regard. There are preliminary studies showing that single-walled carbon nanotubes can carry current density levels larger than metals can by orders of magnitude and, during the process, Joule heating may occur at significantly smaller levels compared to metals. It gets rid of the heat problem and eliminates the need for cooling mechanisms."



Single-walled carbon nanotubes may help beat the heat in future power electronics packages. (Source: Wikipedia)

While their work in carbon nanotubes is in the preliminary stages, Basaran said that they're currently

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