

# Nanotech: Hot Technology Gets a Cool Down

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It's the hottest technology – featherweight laptops that feature rapid response, crisp graphics and operate complex computer games; slim cell phones with Web-browsing capabilities, store high resolution photos and keep track of our lives; credit card-sized MP3 players that store thousands of songs and hours of videos.

But as those gadgets get smaller, more portable, and are asked to do more, they are getting hotter – as in overheating. Electronic appliances that once were large enough to be cooled by fans are now in danger of malfunctioning because there is no easy way to remove all the excess heat produces by large numbers of tiny transistors operating inside them.

“It’s a major problem that could limit the ability to make all electronics smaller and at the same time faster and more powerful,” said Alexander Balandin, a UCR professor of electrical engineering.

To that end, Balandin recently received a \$600,000 grant to help devise such technology. The three-year project, funded by the Air Force Office of Scientific Research (AFOSR), aims to increase the speed of the next generation of electronic and optoelectronic devices while simultaneously reducing heat dissipation and improving thermal management.

Balandin work in this area focuses on phonon engineering, an area of research that he pioneered more than a decade ago.

In tech talk, acoustic phonons are quantized modes of crystal lattice vibrations, which limit electrical conductivity of semiconductors while,

at the same time, carry heat in semiconductors and electrical insulators. Optical phonons strongly influence the light emission properties of materials. Nanometer scale dimensions of the state-of-the-art semiconductor devices and a wide variety of available constituent materials allow one to tune the phonon energy dispersion and, thus, control the ways phonons interact with electrons and other phonons.

The methods of controlling the acoustic phonon interaction with electrons may have a strong impact on how much heat is generated in electronic and optoelectronic devices. Examples of optoelectronic devices include light-emitting diodes (LEDs) used in color displays and traffic lights; photodetectors essential for light-wave long-distance telecommunications; semiconductor lasers widely utilized in medical instrumentation, digital data storage, material processing and safety equipment. As these devices continue to be made smaller and the amount of dissipated power per unit area increases their cooling becomes crucial for continuous use.

Balandin uses the following analogy to describe the motion of electrons through a transistor: A large group of students wearing blue T-shirts – they are the electrons – must, quickly and efficiently, move into a room through one door and out of the room through another door located on the other side of the room. Students in red T-shirts – they are the phonons – are in the room bumping into the blue T-shirt students and – occasionally – the walls of the room. As the size of the room decreases things get more chaotic with more bumping (e.g. scattering in scientific terms). The resulting effect is decreased ability of electrons to move through the transistor channel and increased temperature.

Balandin and his researchers will investigate the use of layers of synthetic diamond incorporated with the conventional silicon layers to better manage the interaction of phonons and electrons. Diamond is known to be an excellent thermal conductor and its use in device

structures for increasing electron mobility will simultaneously improve the heat removal.

Balandin is the director of the Nano-Device Laboratory, which conducts experimental and theoretical research aimed at better understanding phonons in novel materials, nanostructures and devices.

Source: University of California, Riverside

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