Refrigerator on a Chip

Microelectronic and optoelectronic integrated circuits (ICs) often develop hot spots when run near their maximum outputs, which may dramatically diminish the devices' lifetimes. A research collaboration led by John Bowers of the University of California at Santa Barbara and Ali Shakouri (831-459-3821, ali@soe.ucsc.edu) of the University of California at Santa Cruz is working to ensure that ICs keep their cool with tiny thermoelectric (TE) refrigerators built right on top of the chips.

Conventional TE coolers are already used widely to cool semiconductor lasers and other circuitry, but they are manufactured separately from the ICs and later added to the chips. The new superlattice microcoolers are grown directly on silicon surfaces, giving them more intimate thermal contact with the semiconductors and simplifying the overall fabrication process. In addition, TE coolers as small as 40 microns on a side may be precisely located at hot spots to ensure that the cooling winds up in the locations where it can do the most good.

Earlier versions of the microcoolers made of silicon and germanium required buffer layers to ease the strain of matching their lattice structures to the underlying silicon substrate. By adding carbon to the mix, the researchers changed the lattice structure enough that they could do without the buffer layers, improving thermal contact and simplifying fabrication still further.

Although the superlattice microcoolers have chilled semiconductor surfaces by nearly 7 degrees Celsius, they are still shy of the performance necessary for commercial applications. Theoretical calculations, however, show that a single stage microcooler should be able to provide the tens of degrees of cooling required to make them commercially viable. (Xiaofeng Fan et al, Applied Physics Letters, 12 March 2001; text at Physics News Select).

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