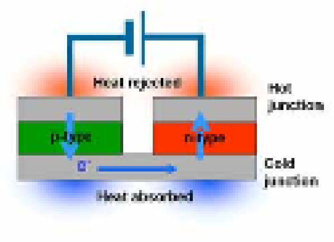
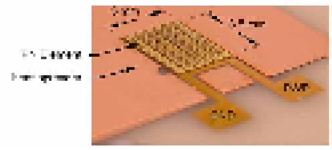
SIDEBAR: Embed Thermoelectric Coolers

Paul Magill, Ph.D., Nextreme

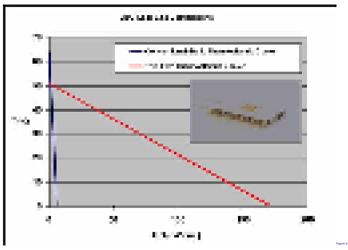


Thermocouples provide the key components of thermoelectric cooling modules. A thermocouple comprises a p-type and an n-type semiconductor element connected by a metal plate (Figure 1). Electrical connections at each end of the p- and n-type material complete an electric circuit. When a source supplies a current, thermoelectric cooling occurs. The thermocouple then "pumps" heat by cooling one side and heating the other by what is known as the Peltier effect.

Scientists have developed thermoelectric materials as thin as 10-20 µm to help cool areas that have an extremely high-heat density. A single thermocouple fabricated using thin-film elements typically measures 600 × 600 × 100 µm. An array of thermocouples of varying densities can form unique embedded thermoelectric coolers (TECs) with different characteristics. Figure 2 shows an embedded thermoelectric component that measures 3.5 mm × 3.0 mm and is only 0.1 mm thick. A package for an IC could include this size thin-film TEC close to the IC's hot spot.



Engineers commonly compare thermoelectric-module performance based on characteristic load lines. A load line describes the maximum temperature difference that a module can sustain across the TEC's thickness as a function of heat-pumping power density. The two end-point values, ?T_{max} and $Q_{max/area}$, define the two extreme ends of a load line. Figure 3 shows load lines for a thin-film TEC and for a conventional TEC.



Measurements took place at room temperature. The inset image in Figure 3 shows the relative size of a thin-film TEC when placed on a conventional bulk TEC. The thin-film TEC offers about over a 100-fold reduction in volume.

The graph in Figure 3 shows a thin-film TEC produces a ?T_{max} of over 50°C across its thickness--think of the thickness of a piece of paper--while it pumps a maximum power density of over 150 W/cm^2. Some benefits of a thin-film TEC include:

1) Unobtrusive integration in or attachment to a heat source. Typically the thin-film material measures at least 20x thinner than the thinnest pellets used in bulk TECs.

2) Power density, which is inversely proportional to the thickness of the thermoelectric material, can approach 30 times more than a typical bulk TEC.

3) Operation in a high coefficient-of-performance (COP) regime while the cooler still pumps heat with a high power density.

4) Systems can control power input to a thin-film TEC to control cooling or heating.

5) A fast thermal-response time constants of 10 msec (nominal), which lets it rapidly cool or heat to maintain precise temperature control.

Figure 4 shows an example of a thin-film TEC implemented between a liquid-cooled cold plate and a lidless IC in a flip-chip BGA package. Because of its low profile, this type of TEC has little impact on package design and makes integration easy for an end-user.

This combination of a thin-film TEC and a liquid-cooled cold plate provides a flexibility not previously available to engineers.

Dr. Paul Magill works at Nextreme, Inc. as the vice president of marketing and business development. He has more than 20 years of experience in the electronics and optoelectronics industry. His expertise covers sensors and laser-diode applications as well as electronics and MEMS packaging and manufacturing. He holds B.S. and Ph.D. degrees in physics from the University of North Carolina.