THERMOELECTRIC REFRIGERATION

Description of technology

Thermoelectric cooling devices utilise the Peltier effect, whereby the passage of a direct electric current through the junction of two dissimilar conducting materials causes the junction to either cool down (absorbing heat) or warm up (rejecting heat), depending on the direction of the current.

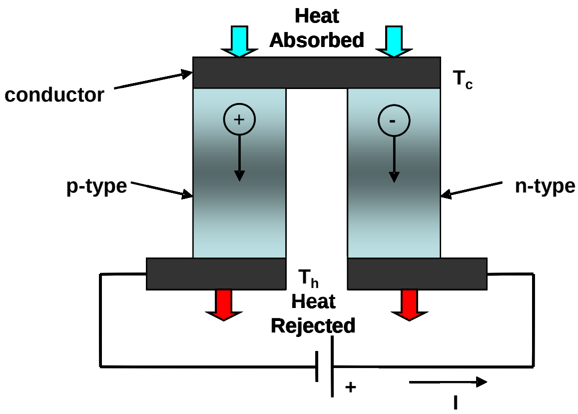

Figure 1 Thermoelectric cooling (or Peltier) couple

Figure 1, shows a pair of adjacent thermo-element legs joined at one end by a conducting metal strip forming a junction between the legs. Thus, the legs are connected in series electrically but act in parallel thermally. This unit is referred to as a thermoelectric couple and is the basic building block of a thermoelectric (or Peltier) cooling module. The thermo-element materials are doped semiconductors, one n-type with a majority of negative charge carriers (electrons) and the other p-type with a majority of positive charge carriers (holes). The majority of commercially available thermoelectric cooling modules are assembled from n-type and p-type thermo-elements cut from bismuth telluride (Bi_2Te_3) based bulk materials.

State of Development

Thermoelectric modules are available commercially to suit a wide range of small and medium cooling duties. Manufacturers' lists include single-stage modules with maximum cooling capacities from less than one watt to 186 W. Maximum heat flux densities are mostly in the range 2-6 W/cm^2 but individual modules with up to 9 W/cm^2 are available. In a thermoelectric refrigeration system the Peltier module (or modules) must be interfaced with heat exchange systems to facilitate heat removal from the refrigerated space to the cold-side and heat rejection from the hot-side to the surroundings. The thermal resistances introduced by the heat exchange systems have a significant influence on the overall coefficient of performance of the refrigeration system.

Applications in the food sector

Thermoelectric modules and systems have been extensively applied in numerous fields, handling cooling loads from milliwatts up to tens of kilowatts with temperature differences from almost zero to over 100 K. They offer advantages of no moving parts and good reliability, absence of noise and vibration, compactness and light weight. They have, however, lower COP and higher capital cost than vapour compression systems. To improve the COP, efficient heat transfer systems are required to reduce the temperature difference across the module. Current applications in the food sector include: hotel room (mini-bar) refrigerators; refrigerators for mobile homes, trucks, recreational vehicles and cars; portable picnic coolers; wine coolers; beverage can coolers; drinking water coolers.

Other potential future applications include domestic and commercial refrigerators and freezers, and mobile refrigeration and cooling systems.

Barriers to uptake of the technology

The main barriers to the uptake of thermoelectric refrigeration are:

- lower efficiency than competing vapour compression technology.
- thermoelectric cooling modules are commercially available but packaged thermoelectric refrigeration systems are not as yet available.

Key drivers to encourage uptake

The main drivers to encourage uptake of thermoelectric cooling technology in the food sector are:

- legislation that significantly limits or prohibits the use of HFCs in small capacity, self contained refrigeration equipment.
- limits imposed on the amount of flammable refrigerant that can be used in self contained refrigerated cabinets.
- increased efficiency of thermoelectric modules.

Research and development needs

Application of thermoelectric cooling technology to the food sector will require improvement of the COPs of thermoelectric refrigeration systems to approach those of vapour compression systems. Ti achieve this it is necessary to develop materials with much better thermoelectric properties than the figures of merit (ZT=1.0) currently available. Research is also required to improve the efficiency of heat exchange systems on both the hot and cold side, to reduce the temperature difference across the Peltier module.