SPICE Model of Thermoelectric Elements Including Thermal Effects

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Abstract

An electrical model for a Peltier cell, based on the analogy between thermal and electrical variables, is proposed. The use of thermal models allows the global performance of thermocooling circuit and signal systems to be checked by using electrical circuit analysis programs such as SPICE. The maximum error in the steady state between measured and simulated temperatures are less than 0.3 °C for hot temperature and less than 0.2 °C for cold temperature with 31.7 °C of temperature change.

1. Introduction

Thermoelectric coolers (TEC) are versatile temperature control devices. Among the many profits provided by the TEC devices it can found the following:

- They don't have moving parts.
- They are used in applications where space limitations and reliability are paramount.
- They don't have CFC's.
- They may be used for heating or cooling by reversing the direction of current flow.

Presently, we are working in the development of a low-cost pollutant gas detector based on infrared optical absorption spectroscopy [1][2]. We use a PbSe array of 64 pixels [3] as sensor element, this array incorporate a TEC device. The TEC element is necessary because dark current characteristics of photoconductors have a big dependence on the temperature. In our case, if temperature increases 1 °C, around 298 K, then the PbSe dark resistance increases close to 3% [4][5][6]. The variation of characteristics may be misunderstood as a variation of the concentration of pollutant gases.

The thermoelectric cooling cell that includes the PbSe array has a heat pumping capacity of 0.97 W. We need a cold temperature in the TEC around -20 °C and a stability of temperature around 0.5 °C for a resolution of 2 ppm in the calculation of the gas concentration.

Development of a TEC model for PSPICE circuit simulation program allows the TEC cells to be included in the computer-aided design of accurate control circuits.

A SPICE model is proposed for thermoelectric elements that are based in the Peltier effect [7][8]. The model has been validated and the error between measured and simulated temperatures in the steady state is less than 0.5 °C.

2. Physical phenomena

Four basic physical phenomena can be associated with the operation of thermoelectric devices: The Seebeck effect, the Peltier effect, the Thomson effect, and the Joule effect. The Seebeck effect is the voltage generated when a temperature change is maintained between the two sides of a TEC. The Peltier effect is the heating or cooling effect observed when an electrical current is passed through two dissimilar junctions. The Thomson effect is heating or cooling effect in a homogeneous conductor observed when an electrical current is passed in the direction of a temperature gradient. The Joule effect is the heating effect observed in a conductor as an electrical current is passed through the conductor.

A typical TEC module consists of two ceramic plates with several p- and n-type semiconductor (SC) material connected electrically in series and thermally in parallel, see in Fig. 1.
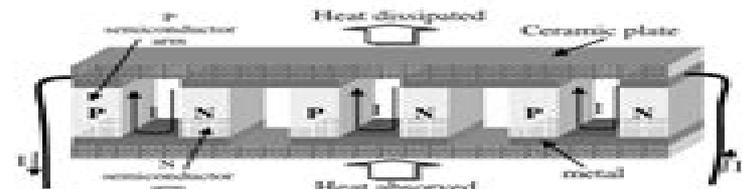

Fig. 1. The schematic of a TEC module.

Firstly, we only consider a SC bar having a different temperature at each end through which the current is flowing, see Fig. 2. Where

T_c is the cold side temperature.
T_h is the hot side temperature.
q_c is the absorbed heat in the cold side.
q_h is the generated heat in the hot side, and
I is the electrical current.

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