Applied Thermal Engineering 38 (2012) 7–13

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Theoretical studies on the efficiency of air conditioner based on permeable thermoelectric converter

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A R T I C L E I N F O

Article history:
Received 2 April 2009
Accepted 5 January 2012
Available online 11 January 2012

keywords:
Thermoelectricity
Thermoelements
Bismuth telluride
Coefficient of performance
Air conditioner

A B S T R A C T

This study presented the thermoelectric air conditioner unit based on permeable cooling thermoelements. In the thermoelectric air conditioner unit the air flow is cooled due to a combined action of thermoelectric effects and the Joule-Thomson effect. On the basis of the optimal control theory the method of designing permeabler thermoelement is described, which makes it possible to determine the optimal structural and thermophysical parameters, including the applied electrical current and the heat carrier velocity in the channels of thermoelements in the mode of maximum coefficient of performance (COP).

Methods for calculation of temperature distribution, cooling capacity, determination of power conversion energy characteristics and thermoelement design in maximum COP mode when thermoelectric materials based on solid solutions of Bi_2Te_3 are given. Results of computer studies for the case of thermoelement legs based on Bi_2Te_3 material have shown the possibility of COP increase by a factor of 1.6–1.7 as compared to conventional thermoelectric systems.

1. Introduction

Thermoelectric cooling systems are environmentally friendly (freon-free), noise-free, noteworthy for simple design, high reliability, random attitude in space, possibility of stepless and precise control of cooling capacity and temperature, which shows their good prospects for creation of air conditioning thermal modes. However, despite such attractive characteristics, thermoelectric cooling systems have not found wide application in solving the problems of domestic thermal stabilization.

In the domestic refrigerator the most used cooling system is the vapour compression, as it has a good value of coefficient of performance (COP). However, the temperature control inside the cooled room is inaccurate, as the compressor makes start and stop cycles, what makes a variation of temperature higher than 8 °C [1]. This has a damaging effect in the preservation of the food. Comparative data on the cooling machines for cameras on ships show that the same weight cooling power thermoelectric refrigerator in 1.7–1.8 times less compression system. Thermoelectric chillers for air conditioning systems have a volume of approximately four and weight three times smaller than the compression refrigerating machines [2].

Thermoelectric refrigerators presented in works [3,4] with a good control in the temperature of the space and thus, a better preservation of the food. However, the cooling system has a lower value of COP and thus, high power consumption.

Possibilities of wide application of thermoelectric cooling are primarily dependent on their energy efficiency, i.e. coefficient of performance (COP). Creation of thermoelectric materials with maximum figure of merit, use of cascade structures and improvement of heat exchange system are considered to be the main lines of COP increase in thermoelectricity.

Methods for improving the figure of merit of thermoelectric materials were stated by A.F.Ioffe as early as the mid twentieth century [5]. They consist in doping substrate material with active impurities to achieve maximum $\alpha^2\sigma$ values and doping material with isovalent substitution impurities to reduce thermal conductivity. These methods were applied to some materials which improved the figure of merit and, respectively, contributed to a wide practical use of thermoelectricity. However, in recent decades, despite numerous studies, further increase in the figure of merit of thermoelectric materials has been minor. New ways of efficiency improvement should be sought for. Therefore, increasing attention is paid to investigation of alternative lines – the one-dimensional and whisker quantum structures, film materials and quantum well composites. Research is also made on thermoelectric materials with programmable inhomogeneity (FGM) helping to improve energy efficiency due to the use of the bulk

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doi:10.1016/j.applthermaleng.2012.01.012