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Submitted 14.06.2019

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EXPERIMENTAL STUDY OF A THERMOELECTRIC COOLING MODULE FOR AN X-RAY DETECTOR

The paper presents the results of experimental studies of a thermoelectric multistage thermoelectric cooling module for X-ray detectors. A specialized bench was developed, a thermoelectric cooling module was manufactured, and a series of its studies was conducted under conditions simulating its operation as part of an X-ray detector. Bibl. 6, Fig. 3.

Key words: experimental study, thermoelectric cooling, X-ray detector.

Introduction

General characterization of the problem. Thermoelectric cooling is rather widely used to assure the necessary operating temperature of various radiation detectors [1 – 3]. The detector device, arranged on the heat-absorbing surface of thermoelectric cooling module, as a rule, is mounted into a sealed housing, the basis of which is in good thermal contact with the heat exchanger.

Single-stage thermoelectric modules are used for shallow cooling of radiation sensors to ~ 250 K. Two-stage thermoelectric coolers (TEC) are used to cool sensors to operating temperature 230 K, three-stage TEC – to temperature of 210 K, four-stage TEC – to temperature of 190 K [3]. Such converters offer a number of advantages, including small size, durability, high reliability, and up to 20 years of service life.

In [6], a computer-aided design of a four-stage thermoelectric cooling module was performed to provide the temperature and thermal conditions for the operation of an X-ray detector.

The purpose of this work is to experimentally verify the results of simulating a thermoelectric multistage cooler for an X-ray detector.

TEC design

As a result of computer design and optimization, the structure of thermoelectric cooler for an X-ray detector was developed (Fig.1) which comprises 4 stages with 6, 12, 27 and 65 pairs of legs (with dimensions 0.6 x 0.6 x 1.8 mm^3) of thermoelectric material based on n- and p-type bismuth telluride (Bi_2Te_3) with the overall dimensions 12 x 16 x 12 mm^3. The size of cooled area is 4 x 8 mm. Electric insulating plates are made of aluminum oxide (Al_2O_3) 0.5 mm thick, electric interconnects – of copper (Cu) with anti-diffusion nickel layer (Ni) 0.1 mm thick.

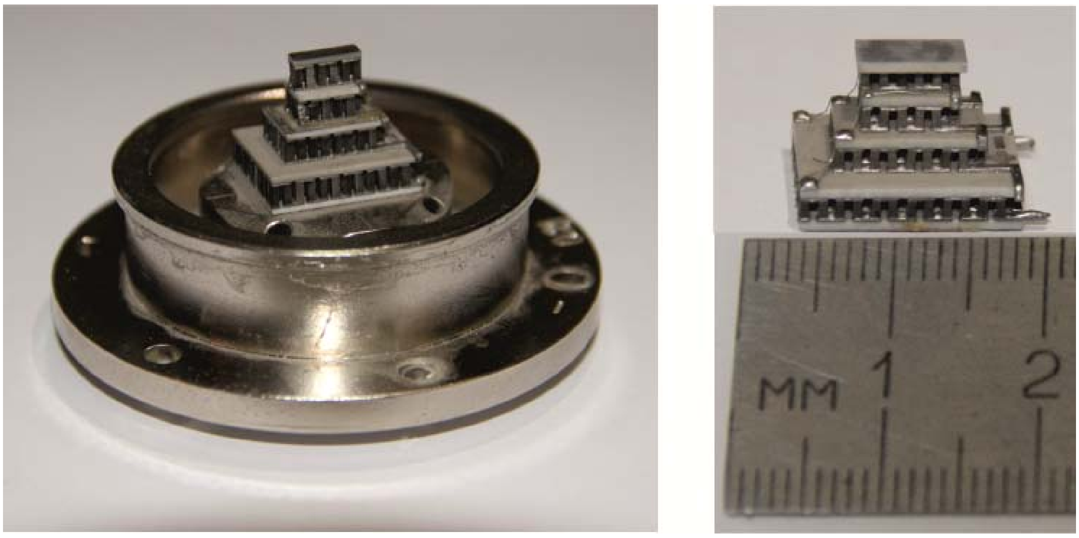

Fig. 1. Appearance of thermoelectric cooling module for an X-ray radiation detector

To conduct experimental studies of thermoelectric multi-stage cooler of X-ray detectors, special measuring bench was developed for maximum reproduction of its operating modes (Fig.2).

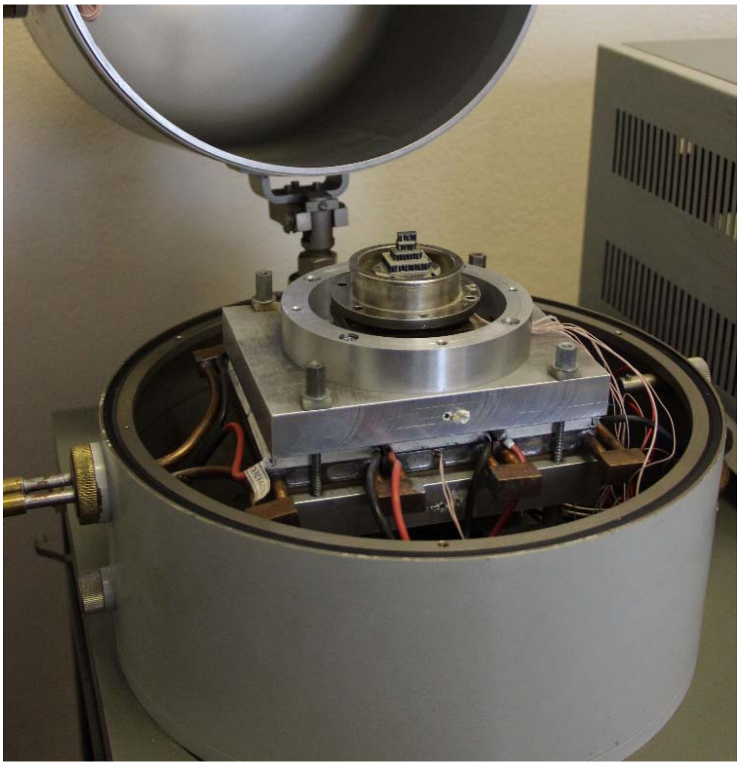

Fig. 2.Appearance of thermoelectric cooling module for an X-ray radiation detector

The bench consists of a vacuum post for reproduction of medium inside an X-ray detector, a thermoelectric multi-stage cooling module proper, a thermal load simulating furnace, a system for heat removal and a set of measuring thermocouples.

Results of experimental studies

Measuring process took place in vacuum, electric power to thermoelectric module was supplied by means of special thermal leads. On the upper surface of the thermoelectric module (the cold side of the thermoelectric module on which the X-ray detector is located), a heat flow simulator furnace was placed. The measurements were carried out using special thermocouples (chromel-kopel thermocouples).

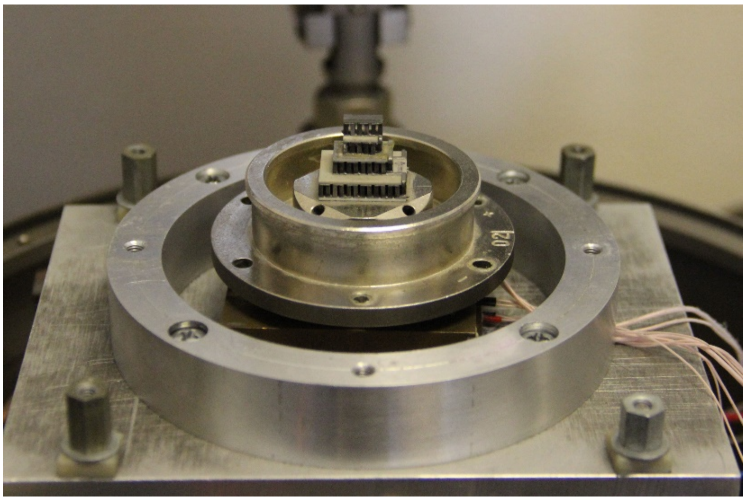

Fig. 3. Appearance of thermoelectric cooling module in measuring bench

During measurement, the main results of designing thermoelectric cooling module for an X-ray detector have been confirmed:

- maximum temperature difference ΔT_{max} = 102 K at detector base temperature T_c=-70 °C;
- electric power W=3 W;
- coefficient of performance ε ≈ 0.018.

The results obtained prove the possibilities of using thermoelectric coolers for assuring temperature and thermal conditions for X-ray radiation detectors and outperform the well-known world analogs.

Conclusions

1. A thermoelectric cooler of an X-ray detector was manufactured comprising 4 stages of Bi_2Te_3 thermoelectric material with overall dimensions 12 x 16 x 12 mm while assuring cooled area 4 x 8 mm.
2. A special bench was developed and a series of measurements of the parameters of thermoelectric cooling module for an X-ray detector was carried out.
3. The electric power of thermoelectric converter W = 3 W was measured, which at the coefficient of performance ε = 0.018 assures the detector base temperature $T_c^{(1)}$ = -70 °C and ΔT_{max} = 102 K.
4. The measurements in general repeat the results of computer-aided design of the thermoelectric cooling module for X-ray detectors and confirm that the developed TEC outperforms the well-known world analogs.

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Submitted 20.06.2019

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ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ТЕРМОЕЛЕКТРИЧНОГО МОДУЛЯ ОХОЛОДЖЕННЯ ДЕТЕКТОРА РЕНТГЕНІВСЬКОГО ВИПРОМІНЮВАННЯ

У роботі наведено результати експериментальних досліджень термоелектричного багатокаскадного термоелектричного модуля охолодження рентгенівських детекторів. Розроблено спеціалізований стенд, виготовлено термоелектричний модуль охолодження та проведено серію його досліджень в умовах, що імітують його роботу у складі детектора рентгенівського випромінювання. Бібл. 6, рис. 3 .
Ключові слова: експериментальне дослідження, термоелектричне охолодження, рентгенівський детектор.

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