Breakthrough Heating and Cooling Technologies Using Novel Solid State Functional Materials

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Abstract

In recent decades, there have been a number of remarkable breakthroughs in energy conservation, one of which is related to the development of new types of solid-state light sources. The discovery of new semiconductor materials, in particular GaN and heterostructures based on them, made it possible to create blue and white LEDs and lasers, which have orders of magnitude greater efficiency and service life than incandescent lamps. This outstanding achievement was awarded the 2014 Nobel Prize. Thus, the energy consumption of all mankind for lighting has decreased by an order of magnitude. The search for these materials took serval decades of hard work of physicists and materials scientists. An even more ambitious project is aimed at reducing energy consumption for cooling and heating by at least an order of magnitude. The fundamental possibility of such a revolution is opened by Carnot's theorem, which allows using not direct energy consumption for heating, but pumping heat using a device called Thomson's heat pump. The efficiency of a heat pump is determined by the efficiency of the process, (COP), which is always more than 1, but less than T1/Δ T, where Δ T = (T1-T0) is the temperature difference between the temperature T1 of a room that is heated and T0 an external environment temperature, from where we take heat, according to Carnot's theorem. At the moment, the liquid materials - freons - are mainly used as a working fluid in Thomson's heat pump. However, the use of freons for pumping heat has practically exhausted itself, at the COP level of the order of 300-400%, and do not grow further. In addition, the use of freons is considered dangerous for the destruction of the Earth's ozone layer. So to reach the predicted level of 1000% is the realistic purpose of the emerging field of solid state heating/cooling. Therefore, the number of scientific works, patents and innovations on the creation of solid-state functional materials for cooling and heating is exponentially growing all over the world. The effects of changes in temperature and heat content that arise in these materials under the influence of external fields are known as multicaloric effects, including the magnetocaloric effect, elastocaloric effect, and electrocaloric effect etc. The maximum value of the caloric effects is achieved near the phase transition point, for example, near the boiling point of freon, or near the Curie point of a magnet or ferroelectric. Therefore, all over the world there is a search for the new solid-state multi-caloric materials, especially with phase transitions. The values of various caloric effects of the order of several tens of Kelvins of temperature changes or several tens of kJ/kg of heat consumption have already been achieved. Also, the devices are being developed that, in principle, in terms of COP could approach the limit of Carnot's theorem. The present report highlights the state of the art record achievements in the study of the properties of solid-state materials for cooling and heating, and record values of COP of multicaloric solid state refrigerators and heat pumps and original results of authors. we describe the formatting guidelines for the conference keynote abstract. We ask that authors follow some simple guidelines. In essence, we ask you to make your abstract look exactly like this document. The easiest way to do this is simply to replace the content with your own material. Please use a 9-point Times Roman font, or other Roman font with serifs, as close as possible in appearance to Times Roman in which these guidelines have been set. The goal is to have a 9-point text, as you see here. Please use sans-serif or non-proportional fonts only for special purposes, such as distinguishing source code text. If Times Roman is not available, try the font named Computer Modern Roman. On a Macintosh, use the font named Times. Right margins should be justified, not ragged.

Keywords: *multicaloric effects, magnetocaloric effect, elastocaloric effect, and electrocaloric effect, solid stste refrigeration*

Hightlight

1. *New solid-state semiconductor materials have already revolutionized lighting technologies for residential and open spaces, reducing the required energy costs by an order of magnitude.*
2. *The fundamental laws of thermodynamics allow for a reduction of at least an order of magnitude a needed energy as well as the cost of home and industrial heating.*
3. *There is an active search all over the world for new solid-state caloric materials that could bring the efficiency of new machines for cooling and heating closer to the ideal Carnot machine.*
4. *The report highlights both the world's best achievements in recent years and the challenges facing the development of advanced solid-state heating and cooling technologies.*

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Short biography

Brief biography of Dr. PhD Victor Koledov

Dr. Dr. Sci. Koledov Victor was born 20 of April 1955 in city Rostov am Don. From 1972 till 1978 he studied in Study of Moscow Institute of Physics and Technology (MIPT) (Technical University) and finished this University 1978 with Dipl. Eng. in Physics and Electronics. In 1986 he has got PhD (Solid State Physics). In 2008 he has done work for Doctor Habilitation of Sciences with the thesis: "Phase transition and giant deformation in Heusler alloys in external fields. " (Kotelnikov' IRE RAS). Since 1982 till now he is working Institute of Radio Engineering and Electronics Russian Academy of Sciences (IRE RAS). Now he is Leading scientist in this IRE RAS. His research areas are experimental studies of magnetic properties, magnetooptics, ferromagnetic domains, semiconductor lasers, fiber optics, ferromagnetic shape memory alloys, functional materials, medical applications of functional materials, multiferroics, strong magnetic fields, giant magnetocaloric effect, micromechanics, nanomechanics, nanomanipulation system based on record small nano-tweezers, mechanical bottom up nano-assembling, superconducting magnetic levitation, photonics, nano-optics.

He has got awards / Prizes / Honours at 2009 Start2grow competition of Businessplan Germany for Nano-tools, 2010 Start2grow competition of Businessplan Germany for MST-technology of Nano-tools. And after this since 2010 he is founder and director of German innovative Innowledgement GmbH.

He is leader of more the 25 national and international projects. Victor Koledov is author and coauthor of more then 180 scientific paper in referred journals and more, then 160 presentations at national and international presentation, among then more than 25 Invited and Keynote speaker. He was invited Professor in – Spain, Italy, Romania, Portugal, China, India, Brazil, South Africa.

He participates in organization of conferences 1. Conference on Manipulation, Automation and Robotics at Small Scales (MARSS). 2. Conference 3 M nano International Conference on Manipulation, Manufacturing and Measurement on the Nanoscale, 3. METANANO 2019,

4. RAMAN OPTRONICS WEBINAR SERIES (ROWS-2021). Conference Organizing Committee Yaseen Academy http://www.yaseen.org.cnhttp://www.yaseen.org.cn

Victor Koledov is supervisor of more than 20 students, and about 10 PhD.

2014, 2018 Nano 3 M Award for invited report, 2018 3M Nano Award as Keynote speaker. Honorary Professor, Changchun University of Science and Technology (CUST) China

Teaching – Victor Koledov is invited Professor in Changchun University of Science and Technology (CUST) China, World-class scientific and educational centers Nanophys IRE RAS, Sirius University Sochi, Russia. University of Oviedo, Spain.