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APPLICATION OF MAGNETOCALORIC COOLING COMPONENTS FOR SMALL SATELLITE SYSTEMS

Abstract

The regulation of the thermal balance in a spacecraft is a complex process. Passive mechanisms are mostly based on simple heat radiation and insulation strategies, which are not always sufficient and bulky, respectively. Especially for payloads, which process and transmit large amounts of data, complex and expensive active mechanisms like liquid cooling circuits or thermoelectric coolers have been necessary until now. The trend towards highly integrated satellites with much higher computational demands also include the utilization of COTS components with potentially high power and heat dissipation. This poses a challenge for future thermal systems, in order to enable applications like AI, SAR pre-processing, compression or 5G communication satellites. Therefore, magnetocaloric cooling (MKM) components for small satellite systems seem an efficient way of spacecraft thermal management and to tackle above mentioned problems. The research proposes a concept of a new type of chip and component cooling functionality, initially adapted to the special boundary conditions and modes of operation in space environment. MKM, i.e. cooling by adiabatic demagnetization of a magnetic solid, originates methodically from low temperature physics. It uses the magnetic field dependence of the entropy of (ferro)magnetic solids. The temperature of a magnetocaloric material can be reduced by cyclically magnetizing and demagnetizing it. The next steps for MKM components is now to further develop this process for applications in space technology. This includes optimizations regarding the miniaturization of such systems, thermal management and magnetic field control. In particular, it is proposed that the step to magnetize can be performed during the eclipse in Earth orbit, whereby a component that is not under heavy use (e.g. OBC or camera CCDs) is first heated without this heating having a strong impact on temperature management. The heat transfer of the magnetocaloric material should then not be done by a cooling medium, but "naturally" by the heat radiation during the eclipse. Thus, no complex handling of cooling media is necessary. The next phase then occurs as soon as the component is under "load" and heats up. The cooling medium is demagnetized and the coupled component is thereby cooled. The paper will elaborate on the theory and concept of MKM in general and the adaption to use in a small satellite thermal system for cooling components like on-board processors. A selection of suitable materials is discussed and characterized, as well as use case scenario and possible further applications.