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Smart and Multifunctional Materials in Electric Propulsion and Cubesats

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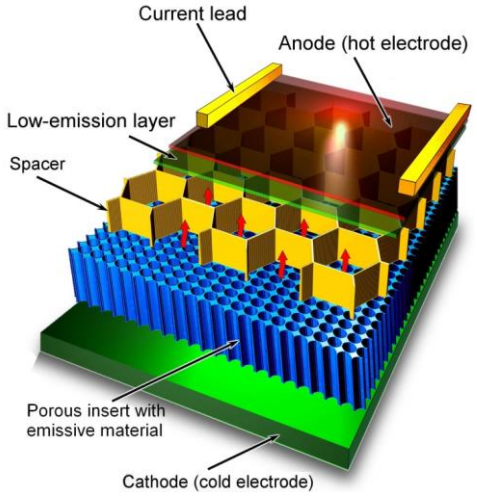

Figure 1. Design of the nanoscaled metamaterial capable of reversal heat transfer by electron emission (concept). The cathode (cold electrode, green) has a temperature lower than that of the anode (hot electrode, red). Nanoporous material contains the liquid (at a work temperature) highly emissive material. Reprinted with permission from I. Levchenko *et. al,* Adv. Mat. Technol. 1, 2016.

Efficient and reliable control systems are among the primary prerequisites for the successful cost-effective space exploration. Communication satellites, manned and cargo spacecraft, small satellites for space remote sensing, scientific instrument for the adjacent and deep space exploration – all of them require precise speed and orientation controls capable of long (several years), robust, and highly efficient operation in the adverse open-space conditions. The criterion of the control system efficiency in the terms of lowest required fuel and mass carrier flow rate, along with the energy efficiency, are the main parameters that directly influence the performance of the whole spacecraft. The electric propulsion-based control systems demonstrate superior characteristics, as compared with the compressed gas, liquid propellant and solid-fuelled thrusters. Without any physical limitations to the exhaust gas velocity (whereas any thermal engines are limited to 6000 m×s-1), the electric propulsion systems and thrusters could ensure very mass-efficient operation. Nevertheless, these systems still require significant advance in the energy efficiency, reliability, service life and controllability. New materials, including the nanostructure-based structures and metamaterials, are among the most promising approaches that can help to solve these challenges. In this work we briefly review the unique features of the nanostructure-based materials in the contexts of their application in the electric propulsion systems and thrusters, with a strong focus to the Hall-effect thrusters which are regarded as the most promising candidates for the long-living space systems, spacecraft and satellites. In particular, the application of vertically-aligned nanotube patterns, nanotube- and graphene-based nanomaterials, as well as complex metamaterials involving nanoscaled structures and related physical effects is discussed. Advantages and disadvantages of these systems are considered. Moreover, a concept of the adaptive thruster is proposed capable of self-adjusting the operation mode by synthesising nanomaterials in the discharge, and depositing them to the proper areas of the acceleration channel, thus actively changing the channel wall conductivity and other characteristics influencing the discharge and thruster operation regime.