Nanotechnology Application for Spacecraft Smart Coatings: Thermal Stabilizing Coating

Mikhail Mikhailov

Tomsk State University of Control System & Radioelectronics, Tomsk, Russia

Thermal control coatings (TCC) are utilized for maintenance of spacecraft temperature on predetermined level due to their optical characteristics: integral absorption coefficient of solar radiation (a_s) and integral emissivity (ε). The ratio of these coefficients determines a temperature of space vehicle at the beginning of flight [$T \sim (a_s/\varepsilon)^{1/4}$]. The integral emissivity (ε) of such coatings has no change in the range of operational temperatures of spacecraft. During flight, there are at least three complicated situations: 1) The absorption coefficient a_s increases due to the effects of space radiations while the integral emissivity (ε) does not change that leads to an increase of space vehicle temperature. Such cases practically occur with any spacecraft at any orbits. Instead of 20 ^oC in the beginning-of-life the temperature of spacecraft can increase up to 40-50 ^oC and above in the end-of-life. 2) The temperature of spacecraft decreases in the shadow of the Earth or other planets due to lack of solar energy. 3) The temperature drop of unlit part of spacecraft's body occurs at the rotating of around its axis.

Mentioned problems can be solved if instead of TCC with temperature independent emissivity to use the coatings with changeable ε obeying certain regularity. The project is dedicated to development of scientific foundations and technological principals of creation of thermal stabilizing coatings (TSC) having properties to manage an emitted power and to maintain on predetermined level of object temperature. Such coatings are called smart or thinking coatings because of their ability to adapt depending on outer energy conditions and at the same time to change their properties in order to operational characteristics remain constant. With increasing (decreasing) thermal load and TSC temperature or with a_s increasing by Δa_s value, the ε increases by Δε value in order to the ratio $(a_s+\Delta a_s)/(\varepsilon+\Delta\varepsilon)$ remains constant and be equaled to a_s/ε that will lead to keep a temperature on the same level.

There are two types of such coatings: with high reflectivity – "optical solar reflectors" and with high absorptivity – "optical solar absorbers". The reflective coatings can be fabricated based on barium titanates, the absorptive coatings – based on manganites with rare-earth elements. Partial substitution of cations by atoms of other elements allows to shift Curie point of these compounds toward region of operational temperatures of space vehicle. Nanopowder as one of three types of components with concentration exceeding calculated one is chosen for synthesis of such compounds. Excessive portion of nanoparticles precipitates on the grain surface of synthesized compound. This portion of nanoparticles works as relaxation centers of primary defects formed by radiations. It leads to increase in the photo- and radiation stability of TSC and period of spacecraft's active life.

A replacement of all used TCC by TSC on spacecraft's bodies, radiators of thermal control, and on various their parts is possible. The TSC can have an especial importance in spacecraft of open (frame) type and nanosatellite requiring the temperature stabilization of individual units and devices.