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EVALUATION OF OPTICAL PROPERTIES OF ADVANCED REFLECTIVITY CONTROL DEVICE FOR SOLAR SAIL BY NUMERICAL SIMULATION

Abstract

Reflectivity Control Device (RCD) is a fuel-free attitude control device for solar sails, which takes advantage of the momentum of the sunlight. This device is thin-film-shaped and applied to the solar sail membrane. The RCD reflects sunlight diffusively and specularly, when the device is ON and OFF states, respectively. This device is applied to attitude control of solar sails by putting the two RCDs across the center of gravity of the solar sail, for example. The efficacy of the RCD was demonstrated by an actual space mission named "IKAROS" launched by Japan Aerospace Exploration Agency (JAXA) at 2010. In the RCD, Polymer Dispersed Liquid Crystal (PDLC) layer is put between two polyimide-film, one of which is aluminum-deposited. The PDLC layer consists of small size droplets filled with nematic liquid crystals, and the polymers which surround the droplets.

However, this conventional RCD, which reflects the sunlight vertically, cannot generate the torque perpendicular to the membrane. To obtain the additional degree of freedom, we are currently developing a new type RCD named Advanced-RCD (A-RCD). The A-RCD reflects the sunlight obliquely instead of vertically. Therefore The sunlight reflected by the A-RCD has a component parallel to the membrane, which generates the torque perpendicular to the membrane. This new type RCD, however, has one drawback. The obliquely reflected light from the A-RCD somehow attenuated than the vertically reflected light from the conventional RCD. To solve this problem and improve the A-RCD, it is necessary to design the device considering the optical properties.

The optical properties of A-RCD have complexity due to the oblique transmitting light through the device. As it is apparent from the optically anisotropic characteristic of liquid crystals, the PDLC layer has polarization effect on the oblique light transmission through the PDLC layer. The multiple oblique reflections at the each interface between the layers also show polarization due to well known Fresnel's law. Furthermore, because the PDLC is an inhomogeneous medium for the oblique transmitting light, the light scattering occurs, even when ON-state.

To consider above-mentioned compound optical properties, we solve Maxwell's equation by using the finite-difference-time-domain method, by which we evaluate the performance corresponding to the design parameters such as reflection angle. The preliminary simulations of the A-RCD suggest that optimal reflection angle is smaller than the angle designed not considering polarization properties. Based on these results, we can expect an improvement of the performance of the A-RCD.