Polarization Properties of Obliquely Transmitting Light through Liquid Crystal Layer in Advanced Reflectivity Control Device with Applications to Solar Power Sail Spacecraft

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Reflectivity Control Device (RCD) is a novel attitude control device for solar sails. 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, respectively. The RCD generates a torque for attitude control, by applying RCDs on the solar sail membrane. In the RCD, Liquid Crystal (LC) layer is put between two polyimide-film, one of which is aluminum-deposited. The LC layer consists of small size droplets filled with nematic LC, and the polymers surrounding the droplets as shown in Fig.1. The RCD was demonstrated by an actual space mission. JAXA launched a world first solar sail named “IKAROS”, which demonstrated RCD as well as photon propulsion. The major problem arose in the operation of “IKAROS” was the deformation of the solar sail membrane that caused acceleration torque perpendicular to the solar sail membrane. This torque is harmful to stable attitude control. Counteracting these effect by thrusters requires fuels, and is become a significant problem when the mission period is long.

As a solution to this problem, we are currently developing a new type RCD named Advanced-RCD (A-RCD) which reflects the sunlight obliquely instead of vertically[1]. The sunlight reflected by the A-RCD has a component parallel to the membrane, which generates the torque perpendicular to the membrane as shown in Fig. 2. This new type RCD, however, has one drawback. The obliquely reflected light from the A-RCD somehow much more attenuated than the vertically reflected light from the conventional RCD. We are now studying this attenuation effect focusing on the polarization properties of the obliquely reflected light in the LC layer. The effect can easily be attributed to the polarization property in nematic LC because the nematic LC molecules are inherently optically anisotropic (see Fig. 3). The polarization property in nematic LC, however, is not able to explain the whole mechanism of the polarization properties at the LC layer. Considering the polarization property at the interface between the LC layer and polymer is indispensable, because reflectance rate at the interface differs depending on the orientation of the light-polarization. In addition, the boundary surfaces between the LC layer and the polyimide layer are also considered to cause complicated polarization. Understanding these phenomena and mechanisms leads to designing better A-RCD. In this context, this paper intends to identify the mechanism of these properties by modeling and experiments.

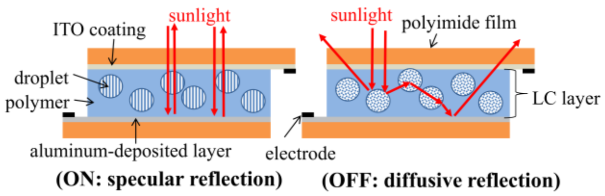

Fig.1. Mechanism of Conventional RCD

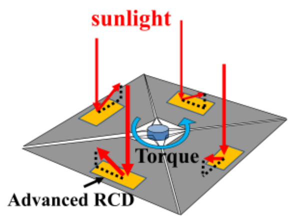

Fig.2. Torque generated by A-RCD

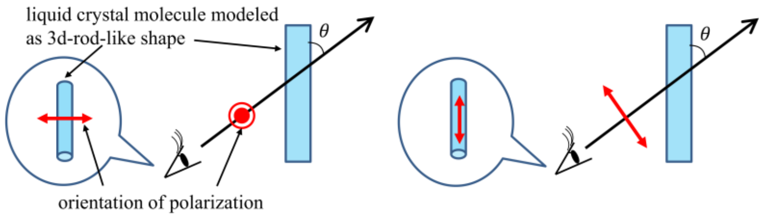

Fig.3. Two polarized lights perpendicular to each other transmit through a liquid crystal molecule in different ways.

References

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