Installing 800 W rated-power solar modules on automobiles has a great potential to reduce CO₂ emission of automobiles. Particularly in Japan, reduction is estimated to be as high as 63%\(^1\). In order to install 800 W of solar modules on automobiles, it is necessary to place the modules not only on the roof, but also on doors and hood. However, since the colors of commercial solar cells are limited to black or deep blue, it limits the appearance and styling of automobiles. Ways to realize colorful solar module have been studied for more than a decade. To realize colorful solar cell, approaches such as dielectric multi-layer (DML) film and dye-sensitized solar cell has been proposed for over a decade, however, the colors generated by DML films is usually angle sensitive and dye-sensitized solar cell are not suitable for its poor durability. In this work, a new approach to realize colored solar module by automotive paint is presented.

Automotive paints consist of layers of highly crosslinked polymers containing absorption driven pigments particles embedded into it. It is however, not possible to directly apply automotive paint to solar panels because a significant part of the sunlight could be blocked due to its opaque nature. In this work we take two approaches to address this issue (1) apply transparent dichroic pigment flakes such as micas that allow part of the sunlight to pass through, (2) Use dilute amount of high-chroma and highly reflective opaque pigment embedded in polymer layers.

The paints with pigment weight concentration (PWC) from 0% to 10% were prepared to check the relationship between PWC and the power or the color. Two types of pigments are used (1) omni directional structural color (OSC) pigments\(^2\) as a highly reflective pigment and (2) standard mica pigment (BASF 9680H) with blue color. The paint was first coated on the glass plate, and was placed on top of ethylene-vinyl-acetate (EVA)—solar cells (back contact-type c-Si)—EVA—black backsheet laminated solar module. The color was then measured for both above the cell (cell region) and above the backsheet (backsheet region) with colorimeter (Konica Minolta cm512m3a_j8). We focused on the color difference between the cell region and the backsheet region which is also a measure of ‘hiding’ performance of the pigment. The colorimeter gives L* a*b* value from CIE1976 L* a* b* color space for each region and the color difference \(\Delta E\) is defined \((\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2)^{1/2}\ where \(\Delta L^*, \Delta a^*, \Delta b^*\) are the differences of L*, a*, and b* value between cell and backsheet region. The output power of the module was measured using solar simulator. The power conservation rate (PCR) was defined as follows: the power with color pigments / the power without color pigments.

The result is shown in Fig.1. “Good Color” indicates that the color difference \(\Delta E\) between the cell region and the backsheet region is below 3 as a necessary hiding power of the color. The large reduction in PCR as PWC increases was observed for OSC, while the mica showed better PCR, keeping above 80% at PWC of 10%. Based on this study we conclude that the mica pigment around 10% PWC keeps a good balance between appearance and power conservation. This work paves the way for a practical approach to realize colorful photovoltaic surface for application for vehicle and beyond.

References:
2. D. Banerjee and M. Zhang, Omnidirectional Structural Color, OSA Technical Digest (Optical Society of America, 2010), paper PDWD13