Design of nanoparticle-loaded solar control interlayer and synthesis of relevant functional nanoparticles

by

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Abstract

Solar light of interest to our daily life is divided into three main wavelength regions. The visible light (380-780 nm) provides natural lighting to the interior of buildings and vehicles. The ultra violet (UV) light (100-380 nm) damages the furniture and the skin, and the near-infrared (NIR) light (780-2500 nm) brings heat to the interior which increases the air-conditioning demand. As the use of glass increases in buildings and vehicles, glazings that can regulate the solar irradiation are essential to energy conservation and green-house gas reduction while maintaining human comfort. Nanoparticle-loaded polyvinyl butyral (PVB) interlayers are significant solar control products with intense academic and commercial research. However, the design of such products has been all empirical and not generalizable. In chapter 1, systematic and scientific procedures for the design of such interlayers are developed following a hierarchical product design framework. Desirable product attributes - transparency, energy savings, pleasant color, etc. and the related product specifications - transmittance of visible light, solar heat gain coefficient, color coordinates, etc. are met by properly selecting the type(s) of nanoparticles. Transmittance and reflectance database is interpreted using fundamental physical principles. Specifically, the localized surface plasmon resonance of the nanoparticles are accounted for using the Maxwell-Garnett relation and Beer-Lambert’s law. The final product that meets all the product specifications as verified by prototypes is obtained by iterating between predictions and experiments. In chapter 2, tungsten bronze nanocrystals, a promising material, were synthesized via a modified wet chemistry method with controlled crystal structures, compositions, and particle morphologies, and the corresponding optical performance were systematically studied. In chapter 3, monodisperse oxygen deficient tungsten oxide nanorods with controlled dimensions and tunable absorption characteristics were successfully synthesized for the first time, which showed an outstanding solar control effect. In chapter 4, novel incorporation of manganese revitalized the localized surface plasmon resonance (LSPR) of digenite copper sulfide nanocrystals, which are thermally more stable than common covellite copper sulfide nanocrystals. The copper sulfide nanoparticles were applied in solar control for the first time. The design procedure as well as the novel nanomaterials is expected to help shorten the time-to-market of novel and improved solar control interlayers, and the corresponding laminated glass products.