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Extremely Stable Perovskite Nanoparticles Films for Next-Generation Displays

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Researchers have reported an extremely stable cross-linked perovskite nanoparticle that maintains a high photoluminescence quantum yield (PLQY) for 1.5 years in air and harsh liquid environments. This stable material's design strategies, which addressed one of the most critical problems limiting their practical application, provide a breakthrough for the commercialization of perovskite nanoparticles in next-generation displays and bio-related applications.

According to the research team led by Professor Byeong-Soo Bae, their development can survive in severe environments such as water, various polar solvents, and high temperature with high humidity without additional encapsulation. This development is expected to enable perovskite nanoparticles to be applied to high color purity display applications as a practical color converting material. This result was published as the inside front cover article in Advanced Materials.

Perovskites, which consist of organics, metals, and halogen elements, have emerged as key elements in various optoelectronic applications. The power conversion efficiency of photovoltaic cells based on perovskites light absorbers has been rapidly increased. Perovskites are also great promise as a light emitter in display applications because of their low material cost, facile wavelength tunability, high (PLQY), very narrow emission band width, and wider color gamut than inorganic semiconducting nanocrystals and organic emitters.

Thanks to these advantages, perovskites have been identified as a key color-converting material for next-generation high color-purity displays. In particular, perovskites are the only luminescence material that meets Rec. 2020 which is a new color standard in display industry.

Figure 1: Photographs of large-area siloxane-encapsulated perovskite nanoparticle films. The left one indicates the perfect color converting property on commercial mobile phone screens. The right one presents color converted films under versatile bending states.

However, perovskites are very unstable against heat, moisture, and light, which makes them almost impossible to use in practical applications. To solve these problems, many researchers have attempted to physically prevent perovskites from coming into contact with water molecules by passivating the perovskite grain and nanoparticle surfaces with organic ligands or inorganic shell materials, or by fabricating perovskite-polymer nanocomposites.

These methods require complex processes and have limited stability in ambient air and water. Furthermore, stable perovskite nanoparticles in the various chemical environments and high temperatures with high humidity have not been reported yet.

The research team in collaboration with Seoul National University develops siloxane-encapsulated perovskite nanoparticle composite films. Here, perovskite nanoparticles are chemically crosslinked with thermally stable siloxane molecules, thereby significantly improving the stability of the perovskite nanoparticles without the need for any additional protecting layer.

Siloxane-encapsulated perovskite nanoparticle composite films exhibited a high PLQY (> 70%) value, which can be maintained over 600 days in water, various chemicals (alcohol, strong acidic and basic solutions), and high temperatures with high humidity (85℃/85%). The research team investigated the mechanisms impacting the chemical crosslinking and water molecule-induced stabilization of perovskite nanoparticles through various photo-physical analysis and density-functional theory calculation.

Figure 2. Schematic illustration of the water-induced stabilization of siloxane-encapsulated perovskite nanoparticles.

The research team confirmed that displays based on their siloxane-perovskite nanoparticle composite films exhibited higher PLQY and a wider color gamut than those of Cd-based quantum dots and demonstrated perfect color converting properties on commercial mobile phone screens. Unlike what was commonly believed in the halide perovskite field, the composite films showed excellent bio-compatibility because the siloxane matrix prevents the toxicity of Pb in perovskite nanoparticle.

By using this technology, the instability of perovskite materials, which is the biggest challenge for practical applications, is greatly improved through simple encapsulation method.

“Perovskite nanoparticle is the only photoluminescent material that can meet the next generation display color standard. Nevertheless, there has been reluctant to commercialize it due to its moisture vulnerability. The newly developed siloxane encapsulation technology will trigger more research on perovskite nanoparticles as color conversion materials and will accelerate early commercialization,” Professor Bae said.

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