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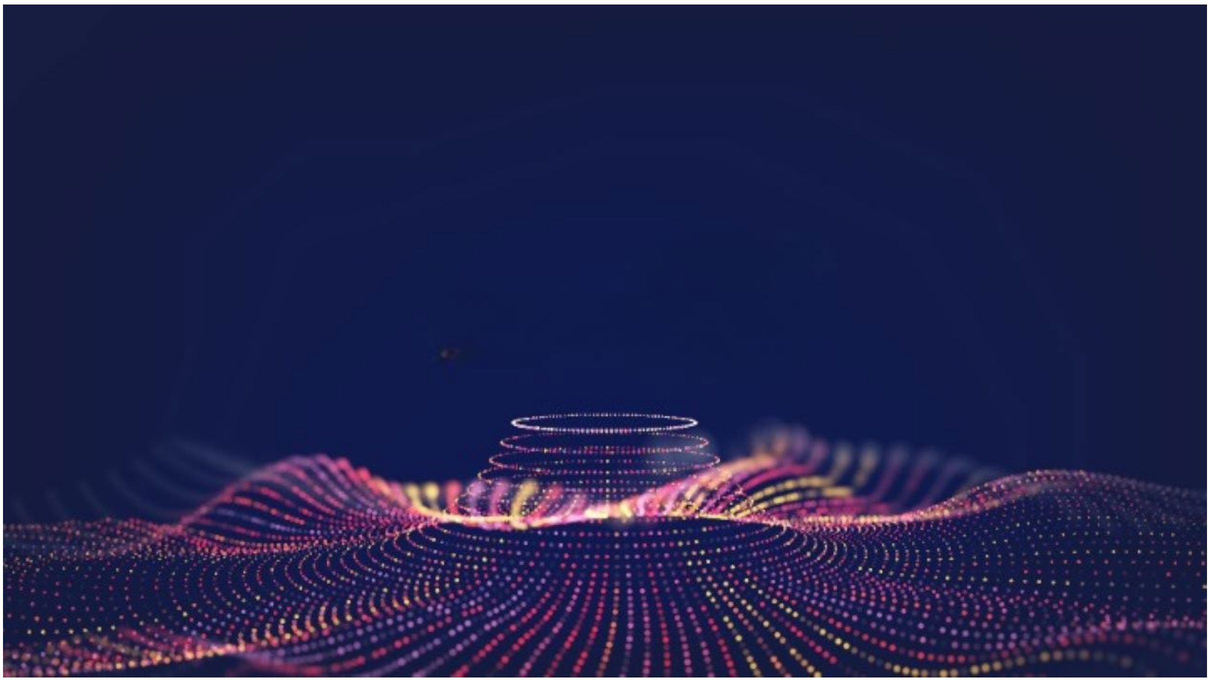
**NTU Develops Colour-Changing Materials for Next-Gen Tech**



Researchers at Nanyang Technological University (NTU) have developed groundbreaking semiconductor materials capable of changing colour with temperature variations. This innovation can potentially advance applications in optoelectronics, smart coatings, and heat-sensitive materials.

The study marks a significant step in leveraging 2D halide perovskites for practical use, particularly in emerging fields where adaptive and responsive materials are crucial. The ability to combine optical tunability with thermochromic behaviour makes these perovskites a game-changer for developing next-generation technologies.

This study focuses on two-dimensional (2D) halide perovskites, exceptional semiconductors known for their structural versatility. These materials can incorporate a wide range of organic molecules, which not only influence their layered structures but also enhance their optoelectronic characteristics. This makes them ideal candidates for devices such as solar cells and light-emitting diodes.

The team, led by Associate Professor Nripan Mathews from NTU's School of Materials Science and Engineering, developed four innovative types of two-dimensional perovskites. These materials were created using a novel approach that incorporates a non-toxic solvent, dimethyl carbonate, as a structural template. This method enabled the synthesis of perovskites with unique and highly stable configurations.

Unlike traditional perovskites, these materials exhibit unique structural arrangements. The solvent molecules are strategically positioned between the organic layers, creating strong hydrogen bonds that stabilise the structure. This design prevents the layers from collapsing into each other, resulting in exceptionally thin spaces between them – some of the smallest gaps ever recorded for solvent-integrated two-dimensional perovskites.

Dr Ayan Zhumekenov, a research fellow and lead author of the study, utilised DMC to achieve precise tuning of the perovskites' band gap. The band gap, a critical property determining a material's colour and electrical conductivity, could be modified by adjusting the ratio of methylammonium to DMC. Density functional theory (DFT) calculations confirmed that these crystals possess direct-band-gap characteristics.

The optical properties of the synthesised perovskites were found to be similar to other 2D perovskite systems, exhibiting narrow photoluminescence signals that indicate their potential in high-performance optoelectronic devices. The researchers also identified a hierarchy in phase stability based on hydrogen-bond distances, with stability decreasing in the order $MA_3(DMC)Pb_2I_7 > MA_4(DMC)Pb_3I_{10} > MA_2(DMC)PbI_4 \sim MA_3(DMC)Pb_2Br_7$.

Among the four compounds, one demonstrated a remarkable thermochromic property, changing colour in response to temperature fluctuations. When heated to 80°C, the material shifted from orange to red and returned to its original state upon cooling to room temperature. The process was repeatable for over 25 cycles, showcasing the material's durability and functionality.

This thermochromic switching capability opens up opportunities for innovative applications such as smart coatings that respond to heat and heat-sensitive inks that change colour at specific temperatures. Such applications could be integral in temperature-monitoring systems, energy-efficient building materials, and responsive packaging solutions, driving further interest in this class of materials.

This research highlights the unconventional role of noncharged solvent molecules like DMC in influencing 2D perovskite structures. By acting as structural templates, these molecules enable unique functionalities, such as tunable band gaps and thermochromic behaviour.

The team hopes their findings will inspire further exploration of 2D halide perovskites for applications in optoelectronics, including advanced solar cells, light-emitting diodes, and other temperature-responsive technologies.

In addition, collaborations with industrial partners could fast-track the development of these materials for consumer and industrial markets. Their high versatility also makes them attractive for multifunctional devices, merging aesthetics with performance.

Their innovation not only demonstrates the potential of 2D perovskites in scientific research but also sets the stage for practical implementations that could transform industries ranging from energy to smart materials. Future studies could focus on enhancing material stability and scaling production to meet the demands of commercial applications, ensuring these materials contribute to real-world technological advancements.

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