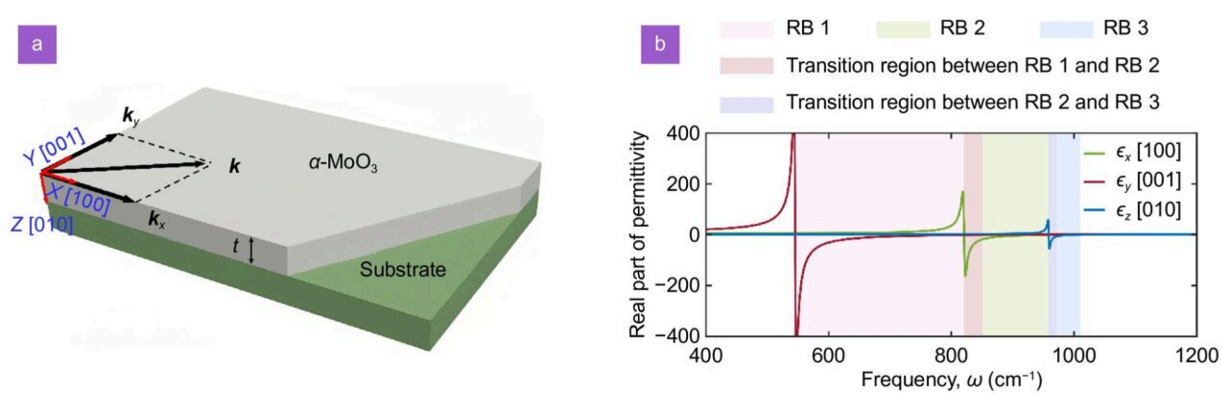
Boosting UV light absorption in 2D semiconductor with quantum dot hybrids for enhanced light emission

July 8 2024



(a) Schematic of α-MoO_3/substrate heterostructure, where the substrate is SiC or Au. (b) Real parts of the components of the dielectric tensor of α-MoO_3 along the principal directions. The Reststrahlen bands are shaded in different colors. Credit: *Opto-Electronic Science* (2024). DOI: 10.29026/oes.2024.240002

A new publication in *Opto-Electronic Science* discusses boosting UV light absorption in a 2D semiconductor with quantum dot hybrids for enhanced light emission.

Two-dimensional (2D) transition metal dichalcogenides (TMDs) have emerged as a promising class of materials due to their remarkable properties. These materials, such as monolayer tungsten disulfide (1L-

WS_2), are just a few atoms thick, yet they possess intriguing electronic and optical characteristics that make them highly attractive for various applications, from flexible electronics to optoelectronic devices.

However, despite their potential, 2D TMDs have their limitations. One significant drawback is their weak light absorption and poor light emission properties, especially in the ultraviolet (UV) range. This weakness restricts their performance and utility in applications requiring UV light interaction, such as UV light-emitting diodes (LEDs), sensors, and photodetectors. Overcoming this limitation is essential to fully unlock the potential of these materials in UV-related technologies.

Quantum dots (QDs) offer a promising solution to enhance the light-absorbing and light-emitting capabilities of 2D TMDs. QDs are tiny semiconductor particles with unique optical and electronic properties, including size-dependent energy levels. When integrated with 2D materials, QDs can absorb a wide range of light energies, including UV light, and efficiently convert them into visible light. This property makes them ideal candidates for improving the performance of 2D TMDs in UV optoelectronic applications.

In this study, researchers aimed to enhance the UV light absorption and emission properties of monolayer tungsten disulfide (1L-WS_2) by incorporating quantum dots derived from 2D materials (2D/QD hybrids). Specifically, they focused on two types of quantum dots: titanium nitride MXene quantum dots (Ti_2N MQDs) and graphitic carbon nitride quantum dots (GCNQDs). These quantum dots were selected based on their strong UV absorption capabilities and environmentally friendly nature, making them suitable candidates for integration with 1L-WS_2 UV light harvesting.

To create the hybrid materials, the researchers synthesized Ti_2N MQDs and GCNQDs using specific chemical processes, ensuring their uniform size and dispersity. They then prepared 1L-WS_2 flakes from bulk WS_2 and deposited them on top of the dispersed quantum dots. This integration process aimed to enable efficient energy transfer from the quantum dots to the 1L-WS_2 layer, thereby enhancing its UV light absorption and emission properties.

Upon investigating the optical properties of the hybrid materials, the team observed a significant enhancement in the UV light absorption and emission of 1L-WS_2 when combined with Ti_2N MQDs or GCNQDs. Under UV light excitation at a wavelength of 300 nm, the hybrid materials exhibited a remarkable increase in light emission intensity compared to pristine 1L-WS_2 flakes.

Specifically, 1L-WS_2 combined with Ti_2N MQDs showed a maximum light emission enhancement by 15 times, while those with GCNQDs exhibited an 11-fold increase in light emission. The enhancement in PL intensity can be attributed to the efficient energy transfer from the quantum dots to the 1L-WS_2 layer. When excited by UV light, the quantum dots absorb the incoming photons and then transfer the absorbed energy to the 1L-WS_2, thereby promoting the emission of visible light.

This process effectively overcomes the inherent limitations of 1L-WS_2 in UV light absorption and emission, leading to a substantial improvement in its optoelectronic performance.

In summary, this study demonstrates a novel approach to enhance the UV light absorption and emission properties of 1L-WS_2 through hybridization with Ti_2N MQDs and GCNQDs. By integrating these quantum dots with 1L-WS_2, the researchers achieved a significant enhancement in light emission under UV light excitation, paving the way for the development of advanced UV optoelectronic devices and other applications.

Furthermore, the environmentally friendly nature of the quantum dots used in this study adds an additional advantage for their widespread utilization in various fields, including biomedical applications.

This work represents a significant advancement in the field of optoelectronics and materials science, particularly in the domain of two-dimensional (2D) materials and their hybrid structures with quantum dots (QD).

More information: Shuo Chen et al, Active tuning of anisotropic phonon polaritons in natural van der Waals crystals with negative permittivity substrates and its application in energy transport, *Opto-Electronic Science* (2024). DOI: 10.29026/oes.2024.240002

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