2-6. Luminescent Materials

Overview

Luminescent materials are substances that emit light in response to external stimuli such as light, electricity, or chemical reactions. They are utilized across a wide range of fields, including displays, lighting, sensors, medicine, and bioimaging. Key categories of luminescent materials include inorganic compounds, organic compounds, organic electroluminescent materials, quantum dots, and perovskites. Inorganic luminescent materials, known for their durability and stability, are commonly used in fluorescent lamps and white LEDs. Organic electroluminescent materials are lightweight and flexible, making them ideal for use in smartphone and television displays. Quantum dots are nanoscale semiconductor particles that offer precise control over emission wavelengths and high color purity. Perovskite materials, which have gained significant attention in recent years, are highly efficient and cost-effective to produce, and are expected to play a major role in next-generation optical devices. When selecting luminescent materials, factors such as luminous efficiency, emission wavelength, lifetime, stability, and environmental impact are critical. Ongoing research aims to develop optimal materials tailored to specific applications.

In Japan, many researchers have been leading this field since the 1970s. For a comprehensive overview up to the mid-2000s, refer to "2-4-3. Luminescent Materials" in the Photochemistry Div Report described in Japanese.
URL: https://division.csj.jp/div-report/02/0220403.pdf

Current Status and Frontiers

Research on luminescent materials has advanced rapidly in recent years, with applications expanding into displays, lighting, medicine, and sensing. Cutting-edge developments include display technologies (organic light-emitting diodes, quantum dots, mini-LEDs), lighting (white LEDs, OLED lighting), medical and biotechnological tools (fluorescent probes, imaging), and data storage (optical memory, quantum dot memory). These applications demand high functionality, efficiency, and versatility. Accurate prediction of excited states is essential for designing luminescent materials, and quantum chemical calculations have become a powerful tool in this area. Future applications are expected to include: (1) Display and lighting: Organic EL, quantum dots, micro-LEDs, (2) Medical and bio fields: Cancer diagnostics, fluorescent probes, phototherapy, (3)

Information and communication: Optical memory, quantum dot memory, circularly polarized light communication.

This section of "Luminescent Materials" covers the following 12 categories:

1. Thermally Activated Delayed Fluorescence (TADF)
2. Photon Upconversion Materials
3. Metal Complexes & Rare Earth Complexes
4. Quantum Dots and Semiconductor Nanoparticles
5. Room-Temperature Phosphorescent Materials
6. Supramolecular Luminescent Materials
7. Aggregation-Induced Emission
8. Circularly Polarized Luminescence
9. Magnetic Circularly Polarized Luminescent Materials
10. Chemiluminescence
11. Bioluminescence
12. Fluorescent Dyes for Super-Resolution Imaging

References

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3. M. Yahiro, C. Adachi, *Fundamentals of Organic Light-Emitting Diodes and Their Fabrication Technologies*, Fundamentals of Materials Science, Vol. 1, Sigma-Aldrich (2009).
4. C. Adachi, H. Fujimoto (Eds.), *Cutting-Edge Organic Light-Emitting Diodes: Fundamental Physics, Materials Chemistry, Device Applications, and Analytical Techniques*, CMC Publishing (2017).
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Future Perspectives and Directions

Challenges to Address Over the Next Decade: Luminescent materials are evolving from simple light sources into smart materials that integrate information, medicine, environmental sensing, and energy solutions. Moving forward, advanced molecular design, integration with quantum technologies, and a focus on sustainability will be key. Luminescent materials are expected to play an increasingly vital role in addressing diverse societal needs.

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