2-6-9. Magnetic Circularly Polarized Luminescence Materials

Overview

Magnetic circularly polarized luminescence (MCPL) is a phenomenon in which circularly polarized luminescence (CPL) is induced in optically inactive materials by applying an external magnetic field. In MCPL, the degree of circular polarization of the emission can be flexibly controlled by an external magnetic field, and this phenomenon can be applied to a wide range of materials such as organic luminophores like pyrene, lanthanide complexes, inorganic phosphors, perovskite quantum dots, and organic radical emitters. The scope of MCPL applications is vast, not only as a next-generation light source, but also expected to drive technological innovations in fields such as information and communication, as well as security.

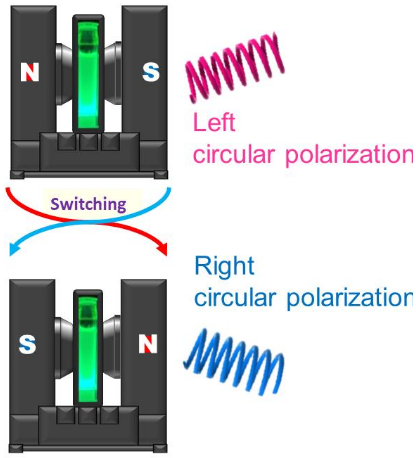

Figure 1. MCPL.

Current Status and Frontiers

CPL is generally emitted from optically active chiral materials. However, when an external magnetic field is applied in Faraday geometry, where the magnetic field vector is oriented parallel to the optical axis, CPL can also be observed from optically inactive substances and materials. This magnetically induced phenomenon is referred to as MCPL. Although magnetic circular dichroism (MCD), an absorption-based effect, has been extensively studied, the excited-state analog, MCPL, exhibits a distinctive capability to induce and modulate the degree of circular polarization in the emission via an external magnetic field.

The MCPL is remarkably versatile and can be applied to a broad spectrum of material classes. Representative examples include optically inactive organic luminophores, such as pyrene, lanthanide-containing organometallic complexes, and inorganic phosphors. Light-emitting diodes (LEDs) are particularly relevant for emissive device applications. The applicability of MCPL has been extended to phosphorescent materials for organic LEDs (OLEDs), particularly platinum and iridium complexes. More recently, cutting-edge material platforms such as perovskite-based quantum dots and organic radical emitters have also been incorporated, significantly expanding the range of photofunctional materials that can exhibit MCPL.

Importantly, this approach enables the extraction of circularly polarized electroluminescence (CPEL) signals under an applied magnetic field. These advances have led to the realization of magnetic CPEL (MCPEL) devices, including magnetic circularly polarized OLEDs (MCP-OLEDs), magnetic circularly polarized perovskite LEDs (MCP-PeLEDs), and third-generation MCP-OLEDs that employ thermally activated delayed fluorescence (TADF). These technological developments have positioned MCPL as a promising foundation for the next-generation circularly polarized light sources.

Magnetic field control, specifically the adjustment of its direction and magnitude, permits rapid and reversible extraction of both left- and right-handed CPL from a single emissive medium. This capability further allows the precise modulation of the degree of circular polarization (anisotropy factor) and facilitates the on/off switching of the CPL output. Moreover, by simultaneously extracting both helicities of CPL from LEDs and integrating a "reflection-inversion" mechanism into device architectures, polarization degradation can be effectively suppressed (Fig. 2). These strategies are expected to enable the development of high-performance, low-cost, circularly polarized light devices with potential applications in advanced security authentication and next-generation information and communication technologies.

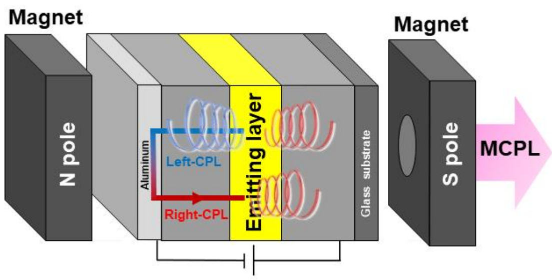

Figure 2. MCP-LED.

Since its discovery, MCPL research has evolved rapidly, encompassing investigations ranging from fundamental photophysical mechanisms to the engineering of advanced optoelectronic devices. The most salient feature of MCPL is that it enables controllable CPL emissions from optically inactive materials without necessitating intrinsic three-dimensional chirality. Continued progress in this domain is expected to have a transformative impact across diverse scientific and technological disciplines, including chemistry, physics, biology, and information engineering.

References

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Future Perspectives and Directions

MCPL materials are expected to undergo rapid research advancements, positioning themselves as key materials that will drive technological innovation across diverse fields, including electronic devices etc. In particular, there is a pressing demand for the development of novel material systems capable of simultaneously delivering distinct MCPL responses and a high degree of circular polarization even under considerably reduced magnetic field strengths, including those enabled by miniaturized magnets.

(Author: Yoshitane Imai)