## 2-5-17. Organic Chiral Materials

### Overview

Photochemical research in Japan has steadily advanced on the foundation of elucidating photoreaction mechanisms based on molecular orbital theory and exploring the dynamics of photoexcited states. Within this tradition, a rapidly emerging focus is on organic chiral materials. Driven by remarkable progress in synthetic techniques for structurally sophisticated chiral molecules, research on the design and application of light-responsive functions that harness molecular chirality has flourished, opening new frontiers in photochemistry.

### Current Status and Frontiers

Recent advances in organic synthesis have led to the development of diverse π-extended chiral molecules, including cyclic architectures, helical π-conjugated systems, and chiral perylene diimide derivatives. These molecules, characterized by frontier orbitals delocalized over extended π-electron frameworks, exhibit exceptional responsivity to external stimuli. Exploiting these properties enables not only highly selective asymmetric organocatalysis but also the creation of next-generation optical materials that selectively respond to circularly polarized light, spintronic materials that interact selectively with electron spin, and hierarchical functional materials constructed through self-assembly.

**1. Circular dichroism (CD) and circularly polarized luminescence (CPL) materials**

The commercialization of CD and CPL spectrometers, together with the development of advanced quantum chemical methods, has greatly accelerated the analysis of chiroptical properties. In parallel, progress in OLED technology has spurred the design of numerous chiral organic luminophores that exhibit CPL. Intensive studies have focused on supramolecular assemblies with chiral emission, chiral dopants to impart handedness, and multi-component systems exploiting energy transfer processes. These efforts have significantly broadened the potential of polarization-controlled light-emitting devices for displays and information processing.

**2. Spin-selective transport and the CISS effect**

Organic chiral materials have also brought new perspectives to electron transport phenomena. In particular, the Chirality-Induced Spin Selectivity (CISS) effect has attracted worldwide attention: electrons traversing chiral molecules can undergo spin polarization. By combining this phenomenon with photoexcited spin dynamics, a new interdisciplinary field bridging photochemistry and spintronics is emerging, opening pathways toward novel device concepts.

**3. Self-assembly and hierarchical structures for functional expansion**

Beyond the chirality of individual molecules, hierarchical organization of molecular assemblies offers opportunities to generate emergent photophysical properties. Through precision molecular design, chiral liquid crystals, supramolecular polymers, and nanofiber assemblies have been realized, many of which display amplified CD and CPL responses on the macroscopic scale as well as remarkable responsiveness to external stimuli. Such systems hold strong promise for applications in optical components and sensing devices.

## References


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## Future Perspectives and Directions

Research on organic chiral materials represents a unique convergence of photochemical traditions in Japan—molecular-level understanding of photoexcited states and photoreactions—with the creation of advanced functional materials. Looking ahead, the integration of quantum chemical simulations and time-resolved chiroptical spectroscopy will enable increasingly precise correlations between chirality and photophysical function. Moreover, expansion into broad application domains such as quantum information processing, biosensing, and spin-polarized devices offers an exciting opportunity for Japan to exert global leadership in next-generation photochemical materials.

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