Efficient and facile induction of room-temperature phosphorescence by confinement of luminescent molecules in heavy atom spaces

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Abstract

The development of room-temperature phosphorescent materials using only organic molecules has been limited due to the complex molecular design and control of specific intermolecular interactions required to induce room-temperature phosphorescence. Our research group has succeeded in constructing a highly efficient and facile room-temperature phosphorescence induction system by confining luminescent molecules inside heavy atomic spaces which are generated by arranging heavy atoms such as bromine and iodine on the pore surface in porous materials. These porous materials can confine a wide variety of luminescent molecules, allowing the color tone, lifetime, and other characteristics of room-temperature phosphorescence to be freely modified depending on the application.

Background & Results

Our research group has reported that a wide variety of porous organic salts (POSs) can be constructed from various organic sulfonic acids and bulky amines. These POSs can be designed to have different sizes, shapes, and surface properties by combining the acids and the amines. These materials led to great expectations for the development of selective adsorption and separation of carbon dioxide and chlorofluorocarbon gases, storage materials for fuel gases such as hydrogen and methane, and other applications in ultra-high sensitive sensing devices for specific chemicals such as toxic substances. In this research, we have established a method that allows flexible chemical modification of the porous material's pore surface.

Designing porous structures using tetrasulfonic acid with an adamantane core and triphenylmethylamine (TPMA-X), in which heavy atoms such as bromine and iodine are introduced at the para position of the phenyl group, led to sodalite-type porous organic salts (s-POS) with large cage-shaped pores as large as 2 nanometers in diameter. On the surface of these pores, bromine and iodine introduced into TPMA-X are exposed, creating a space surrounded by heavy atoms. Confining luminescent polycyclic aromatic compounds (pyrene, coronene, etc.) within these pores enabled extremely efficient and facile room-temperature phosphorescence. The heavy atom space has a large spin-orbit interaction, easily generating the excited triplet state necessary for phosphorescent emission. In addition, the confinement of luminescent molecules in the pores prevents the vibrational deactivation of excitons by heat. In addition, the sodalite-type porous organic salts selectively adsorb only carbon dioxide and do not adsorb oxygen at all, thus suppressing singlet oxygen quenching. As described above, this system developed can efficiently and facilely induce room-temperature phosphorescence even in air at room temperature due to the three effects of heavy atom space.

Significance of the research and Future perspective

Room-temperature phosphorescent materials have been used as light-emitting materials in high-efficiency OLEDs, but their current use is limited to heavy metal complexes with rare metals such as iridium and platinum. From a geopolitical perspective, the systematic development of room-temperature phosphorescent materials that do not use such rare metals and are composed of all-organic materials are desirable.

This system has the potential to efficiently and facilely induce room-temperature phosphorescence in a variety of previously unknown luminescent molecules, and is expected to have a significant impact on the fields of organic electronics, energy conversion and life sciences.

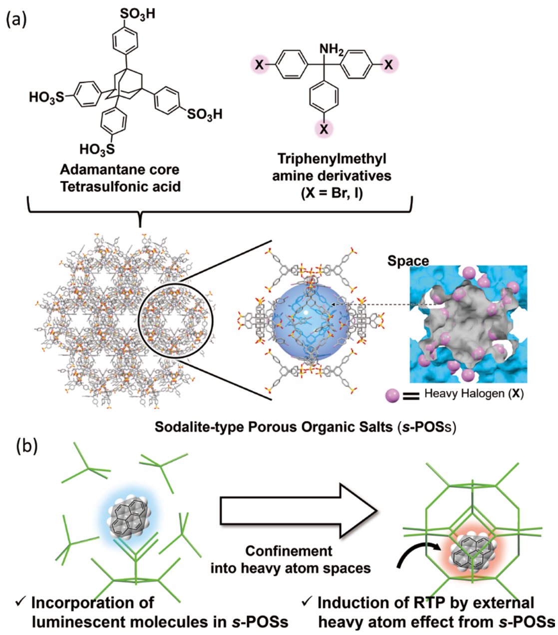

Figure 1. Construction of Sodalite-type Porous Organic Salts and Confinement of Luminescent Molecules in Heavy Atom Space

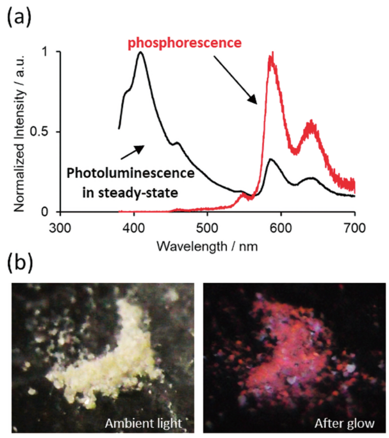

Figure 2. Room-Temperature Phosphorescence Induction of Pyrene by Heavy-Atom Space

Patent

Treatise
Sei, Hiroi; Oka, Kouki; Tohnai, Norimitsu et al. Cage-like sodalite-type porous organic salts enabling luminescent molecule's incorporation and room-temperature phosphorescence induction in air. Small. 2023, 19, 2301887. doi: 10.1002/smll.202301887
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Ami, Takahiro; Oka, Kouki; Tohnai, Norimitsu et al. Porous organic salts: Diversifying void structures and environments. Angew. Chem., Int. Ed. 2022, 61, e202202597. doi: 10.1002/anie.202202597

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