Energy-saving devices, Security, Bio-imaging

# Development of room temperature phosphorescence materials with naturally abundant element


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## Abstract

Organic molecules that exhibit phosphorescence at room-temperature have attracted attention as emissive materials for highly efficient OLED devices and bio-imaging materials with high spatio-temporal resolution, due to their long-lived emission from the excited triplet state. However, existing design strategies for room-temperature phosphorescent materials require the introduction of rare metals and/or heavy elements such as platinum, iridium, and halogens. In this research, we have succeeded in constructing organic molecules that exhibit highly efficient room-temperature phosphorescence with only light and naturally abundant elements, such as carbon, hydrogen, and silicon. We have also demonstrated that the developed molecules actually function as emissive materials for OLEDs and revealed that the external quantum efficiency of the OLEDs reaches one of the world-top-class values for the OLEDs using room-temperature phosphorescent materials that do not contain heavy elements. Furthermore, through systematic structure-property correlation studies, the influence of molecular structure on photophysical processes has been clarified.


## Background & Results

Organic molecules that exhibit phosphorescence at room temperature are attracting attention as emissive materials for highly efficient OLED devices and bio-imaging materials with high spatiotemporal resolution, due to their long-lived luminescence from the excited triplet state. However, existing design strategies for room-temperature phosphorescent materials require the introduction of rare metals and heavy elements such as platinum, iridium, and halogens. In this research, we have succeeded in constructing organic molecules that exhibit highly efficient room-temperature phosphorescence with only naturally abundant and light elements, such as carbon, hydrogen, nitrogen, and silicon. First, we have focused on the electropositive characteristics of the silicon element, one of the most common elements in nature. The introduction of the silicon element into the electron donor moiety of an organic molecule composed of an electron donor and an electron acceptor made it possible to engineer the energy level of the excited state, which was the key to the success of this research. Detailed spectroscopic measurements revealed that the room-temperature phosphorescence is derived through a mechanism of interconversion between energetically proximal neighboring excited states. In addition, we have fabricated OLEDs using the developed molecules and demonstrated that they served as emissive materials in the EL devices. Furthermore, we have demonstrated that the quantum efficiency of the OLED device using room-temperature phosphorescent materials without heavy elements is one of the highest values so far. Furthermore, through systematic structure-property correlation studies, we have elucidated the influence of molecular structure on photophysical processes.

## Significance of the research and Future perspective

In this study, we have found that room-temperature phosphorescence is manifested by a mechanism through which interconversion between energetically proximal neighboring excited states occurs via thermal processes. This result allows us to design room-temperature phosphorescent molecules that do not rely on the introduction of rare metals or heavy elements. In the future, energy-saving optical and electronic devices with high environmental compatibility and sustainability will be realized. In addition, the long-lived luminescence lifetime of phosphorescence can be utilized to develop biologically harmonized imaging materials with high spatiotemporal resolution.

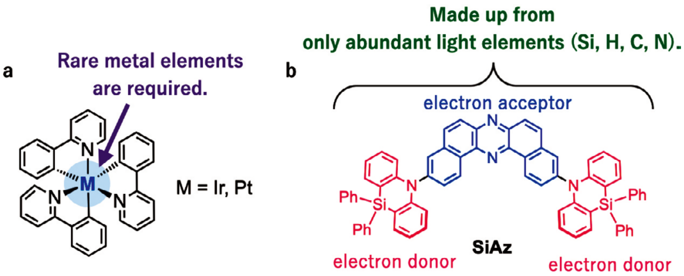


Figure1.a) Conventional RTP materials and b) herein developed RTP material

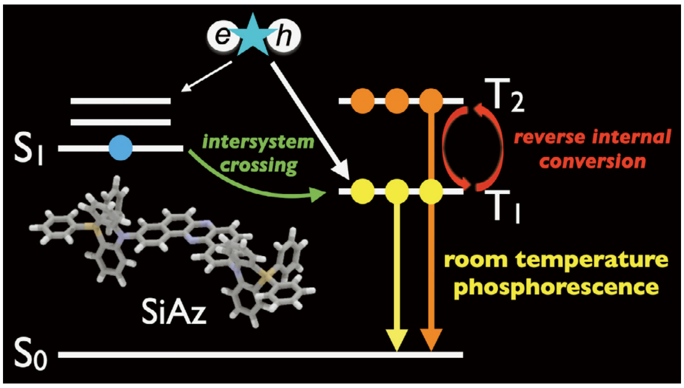


Figure2. The structure of developed room-temperature phosphorescence material (SiAz) and illustrative summary of this work


**Patent** Japanese Patent Application No.2020-541184

**Treatise** De Silva, Piotr; Takeda, Youhei; Data, Przemyslaw et al. Heavy-atom-free room-temperature phosphorescent organic light-emitting diodes enabled by excited states engineering. ACS Appl. Mater. Interfaces, 2021, 13 (2), 2899-2907. doi: 10.1021/acsami.0c17295

De Silva, Piotr; Data, Przamylsaw; Takeda, Youhei et al. The regioisomeric effect on the excited-state fate leading to room-temperature phosphorescence or thermally activated delayed fluorescence in a dibenzophenazine-cored donor–acceptor–donor system. J. Mater. Chem. C, 2022, 10 (12), 4905-4913. doi: 10.1039/D1TC05730H

**URL** http://www.chem.eng.osaka-u.ac.jp/~minakata-lab/ytakeda/

**Keyword** phosphorescence, electroluminescence, emissive material, light energy, elemental strategy