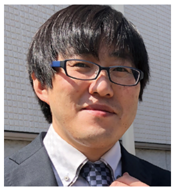
Smart device, Sensor, Security ink, Smart paper

Stimuli-responsive modulation of short-wave infrared-light transparency using a liquescent radical anion



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Abstract

Compounds that can control the transparency of short-wave infrared light (1000–2500 nm) have potential applications as optical filters, security inks, thermal filters, and information storage materials. In this study, we found that a tetracyanoquinodimethane radical anion salt absorbs short-wave infrared light in the solid state at room temperature, while it does not absorb the light in the liquid state at slightly elevated temperatures. Furthermore, it was observed that pressing the liquid state with a needle at a moderate temperature induces liquid-solid phase transition from the pressed area. Consequently, we demonstrated that switching short-wave infrared light from a transparent to an opaque state is possible using the new liquescent radical anion salt.

Background & Results

Radicals are commonly used as reagents (intermediates) in organic synthesis. Due to their high reactivity, it is known that the properties of unpaired electrons in these molecules tend to disappear. However, recent progress in the field of radical chemistry has enabled the synthesis of radical species that retain functions derived from unpaired electrons even in aggregated states. Among these, we are particularly interested in loosely bound radical pairs, focusing on exploring functions derived from their unique electronic structures. In this study, we discovered that a newly designed tetracyanoquinodimethane radical anion salt undergoes a solid-liquid phase transition at a relatively low temperature. Moreover, we found that its transparency to short-wave infrared light (1000–2500 nm) differs significantly between the solid and liquid states.

The designed compound exhibits as a blue solid at room temperature but transforms into a green liquid upon heating to 90 °C. Notably, while the liquid state remains stable at 70 °C, we observed that it transitions to a solid state by external stimulus. By placing the liquid state of the compound between cover glasses and applying pressure with a needle at 70 °C, the liquid rapidly transformed into a solid over a centimeter-wide area. Accompanying this liquid-solid phase transition, the transparency of 1200-nm-light completely switched from a transparent to an opaque state. Various experimental results indicate that the radical anion changes from a monomeric to a dimer state. Along with this change in short-wave infrared transparency, we also observed a switching the magnetic property.

Significance of the research and Future perspective

This radical anion species can be coated onto various surfaces because it can be liquefied, making it adaptable for applications such as on-demand sensors. We believe that the design principles clarified in this study will contribute to advancements across various fields of science and technology.

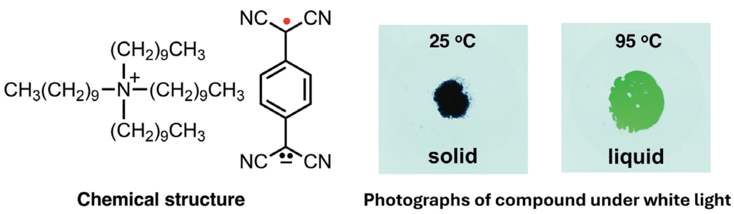

Figure 1

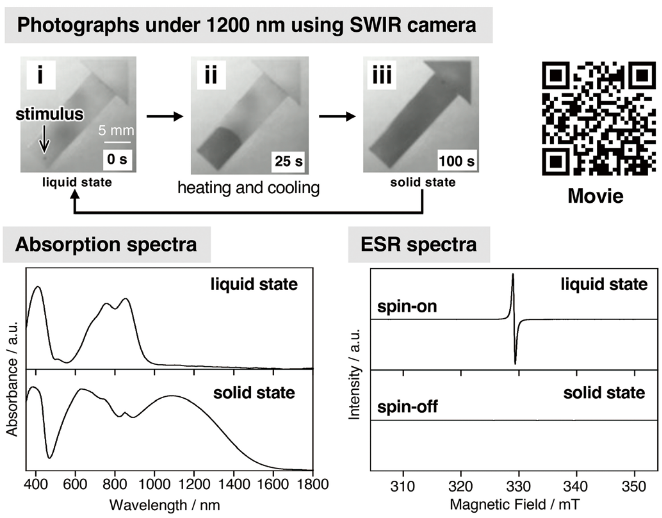

Figure 2

Patent

Treatise: Shu, Ruifeng; Naota,Takeshi; Suzuki, Shuichi. Needlestick-stimulation-induced conversion of short-wave infrared-light transparency using a liquescent radical anion. Small. 2024, 20 (33), 2311557. doi: 10.1002/smll.202311557

URL: https://www.chem.es.osaka-u.ac.jp/soc/home-en/

Keyword: open-sell molecule, stimuli-responsive material, liquescent radical anion salt, short-wave infrared light property