

Electronic Supplementary Information (ESI)

Experimental Procedures

Niobate nanosheets doped or intercalated with a different metal ion (M-NNS, M: metal) colloidal solutions were fabricated by referring to the protocol reported by another group (Ref. 8, T. Ban, et al., 2011) with minor modifications. Samples prepared in this study are summarized in Table 1 in the manuscript body, where the dopant concentrations describe as mol% against a total metal amount, that is, a sum of niobium and M. First of all, liquid niobium(V) ethoxide was mixed with an absolute ethanol solution of a metal chloride (EuCl_3 , CuCl_2 , or LaCl_3) as a dopant. For Ti^{4+} , however, titanium(IV) tetraisopropoxide liquid was added instead of the metal chloride solution. A tetramethylammonium (TMA^+) hydroxide solution was added to the mixture to hydrolyze the metal species followed by aging at 333 K for 24 h with gentle shaking. Total metal concentration and molar ratio of TMA^+ for the total metal contents were set to 0.3 M and unity in final products, respectively. As a reference, an NNS colloidal solution excluding M was also fabricated by the same procedure described above. Particle size distribution of M-NNS in the colloidal solutions was obtained by a dynamic light scattering (DLS) method. Crystal structure of solid components in the solution was analyzed with Raman spectroscopy and X-ray diffraction (XRD) analysis for a thin film sample prepared by drying the NNS colloidal solution on a platinum or glass plate (Fig. 1S). Investigation on photochromic properties of the resultant colloidal solutions was acquired by UV light irradiation from a 300 W Hg-Xe lamp. The experimental setup is illustrated in Fig. 2S. The colloidal solution (2 mL) and a Teflon-coated magnetic stirrer were put in a rectangular quartz cuvette with a path length of 1 cm, then the upper opening was tightly sealed with a quartz plate. UV light irradiation was performed through the quartz plate. During the irradiation, the solution was gently stirred, and temperature of the solution was maintained at 303 K by circulating thermostated water to the cuvette holder. The UV light intensity was constantly adjusted to 25 mWcm^{-2} at $\lambda = 365 \text{ nm}$ (main wavelength), while several other radiations with different wavelengths were simultaneously emitted from the light source (Fig. 3S). After the irradiation for a certain period, change in colour of the solution was evaluated by measuring an optical absorption spectrum with a UV-Vis spectrophotometer.

Supporting figures

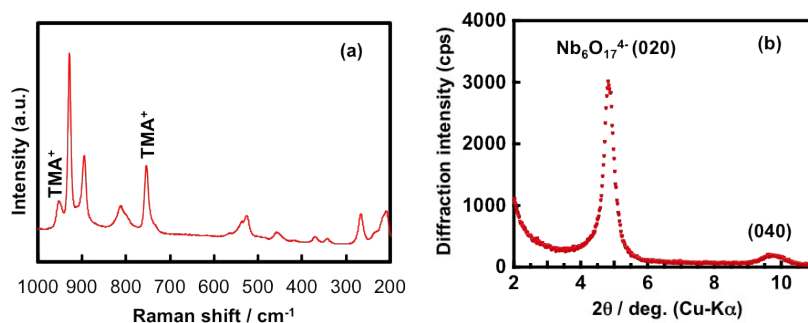


Fig. 1S (a) Raman spectrum and (b) low angle X-ray diffraction pattern of an undoped NNS thin film obtained after drying a colloidal solution of NNS on a Pt plate (a) or a glass plate (b). In the Raman spectrum, the peaks at $200 \sim 300 \text{ cm}^{-1}$ are assigned to bending mode of Nb-O-Nb. The peaks at $800 \sim 950 \text{ cm}^{-1}$ are assigned to stretching mode of NbO_6 octahedra in addition to the peaks attributed to stretching of C-N bonds in TMA^+ (750 and 950 cm^{-1} , denoted as TMA^+ in the spectrum). There is no diffraction peaks in a higher angle region than 11 degree in the XRD pattern.

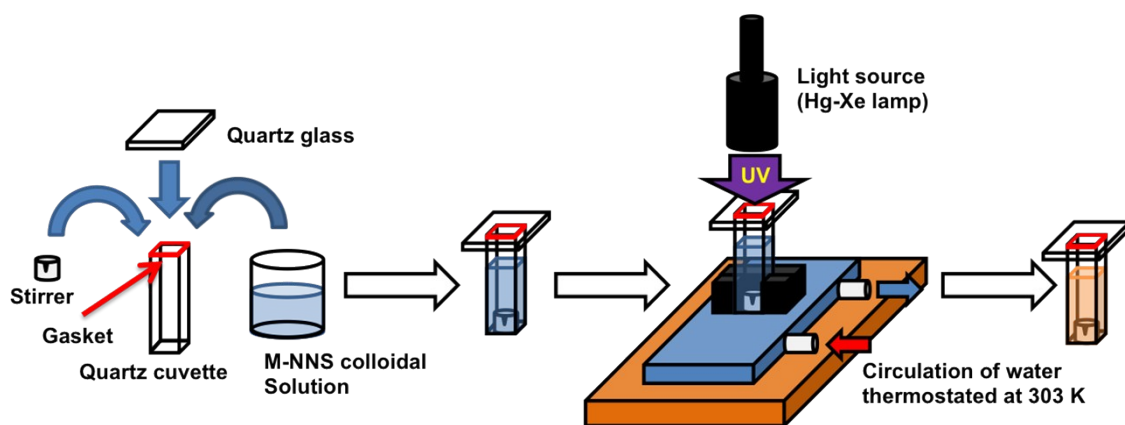


Fig. 2S Schematic illustration of experimental setup for photoirradiation to a colloidal solution of M-NNS.

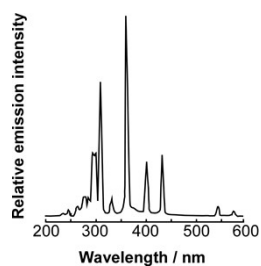


Fig. 3S Emission spectrum of a 300 W Hg-Xe employed to induce photochromism.

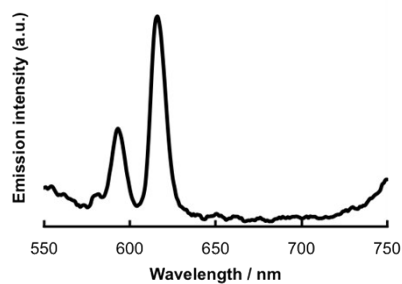


Fig. 4S Photoluminescence spectrum of a colorless Eu-NNS colloidal solution under UV light irradiation.

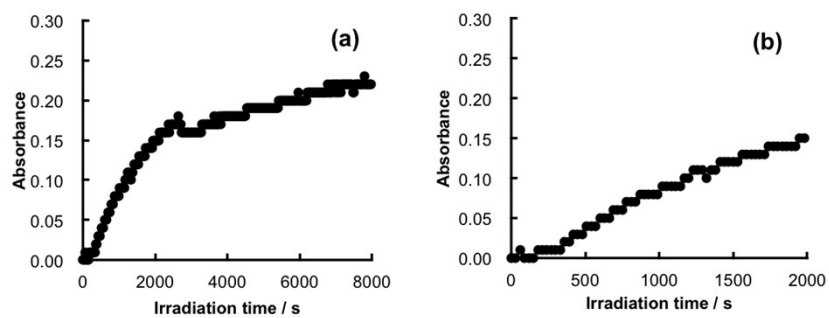


Fig. 5S (a) In-situ monitoring of absorbance change ($\lambda = 550$ nm) of an Eu-NNS colloidal solution during UV light irradiation. (b) Magnified figure of (a) at the initial stage of irradiation.

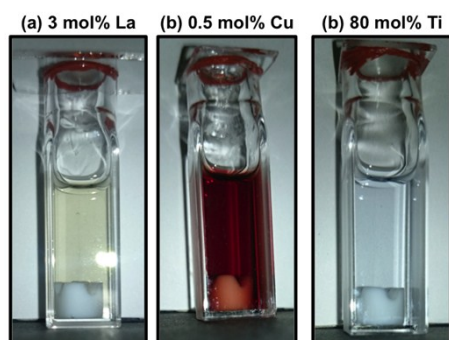


Fig. 6S Photographs of M-NNS (M = La, Cu, and Ti) colloidal solutions after UV light irradiation for 6 h.

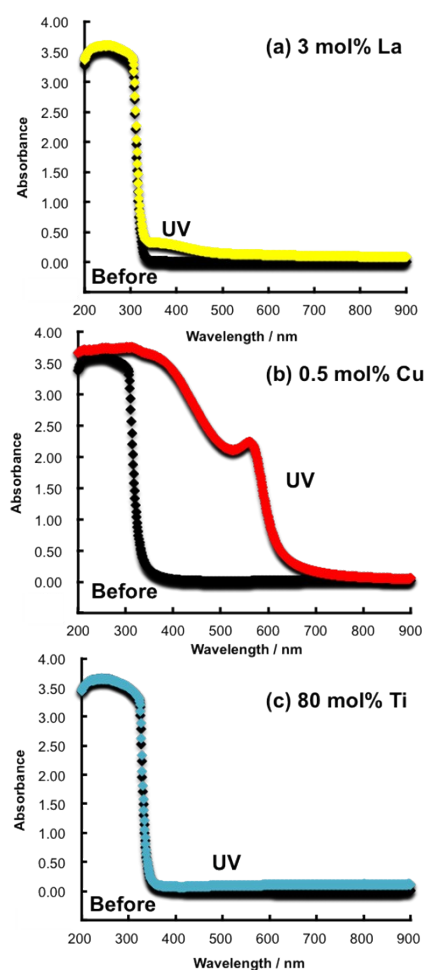


Fig. 7S Photoabsorption spectra of M-NNS (M = La, Cu, and Ti) colloidal solutions before and after UV light irradiation for 6 h.

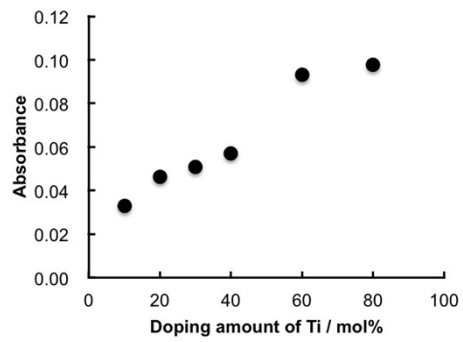


Fig. 8S Influence of Ti mol% in NNS on absorbance at 550 nm after UV irradiation for 6 h. The absorbance before the irradiation was about 0.001 independent of the Ti mol%.