

Electronic Supplementary Information (ESI)

Upcycling waste expanded polystyrene into UV-excited dual-mode multicolor luminescent electrospun fiber membranes for advanced anti-counterfeiting

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Materials and Methods

Materials

PS was from the used product-packaging EPS. Europium hexahydrate ($\text{Eu}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$), terbium nitrate hexahydrate ($\text{Tb}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$), 2-thenoyltrifluoroacetone (TTA) and 1,10-phenanthroline ($\text{Phen} \cdot \text{H}_2\text{O}$) were purchased from Shanghai Dibo Bio-Technique Co., Ltd. Acetylacetonate (AcAc), dichloromethane, sodium hydroxide, anhydrous alcohol and N,N-dimethylformamide (DMF) were purchased from Sinopharm Chemical Reagent Co., Ltd. Industrial alcohol was provided by Jiaying Shengde Chemical Industry Co., Ltd.

Recycling of waste EPS

2 g used product-packaging EPS was cut into small pieces and then dissolved in 40 mL dichloromethane. The solution of PS was precipitated with a lot of industrial alcohol, filtered off, and dried at 60 °C for 12 h in a vacuum oven to yield the recycled PS.

Synthesis of the Eu^{3+} complex and Tb^{3+} complex

1.332 g (6 mmol) TTA, 0.396 g (2 mmol) $\text{Phen} \cdot \text{H}_2\text{O}$ and 0.892 g (2 mmol) $\text{Eu}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$ were dissolved in 6 mL anhydrous ethanol, respectively. The obtained solutions were mixed. The mixture solution was neutralized with 1M NaOH solution. The reaction mixture was heated at 60 °C for 2 h. The obtained precipitate was filtered, washed several times with anhydrous ethanol, and dried at 60 °C for 12 h in a vacuum oven to yield the Eu^{3+} complex. A similar procedure was used to prepare the Tb^{3+} complex by replacing $\text{Eu}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$ and TTA with $\text{Tb}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$ and AcAc, respectively. The mole ratio of $\text{Tb}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$, AcAc and $\text{Phen} \cdot \text{H}_2\text{O}$ is 1:3:1. The synthetic procedure of the Eu^{3+} complex and Tb^{3+} complex and the digital images of the corresponding powder samples under UV lights are shown in Fig. S1.

Characterization

Fourier transform infrared spectra (FTIR) were carried out on a Thermo Nicolet Nexus 470 FT-IR spectrophotometer in the 4000-400 cm^{-1} region using

KBr pellets at room temperature. Digital images were taken using a Nikon camera.

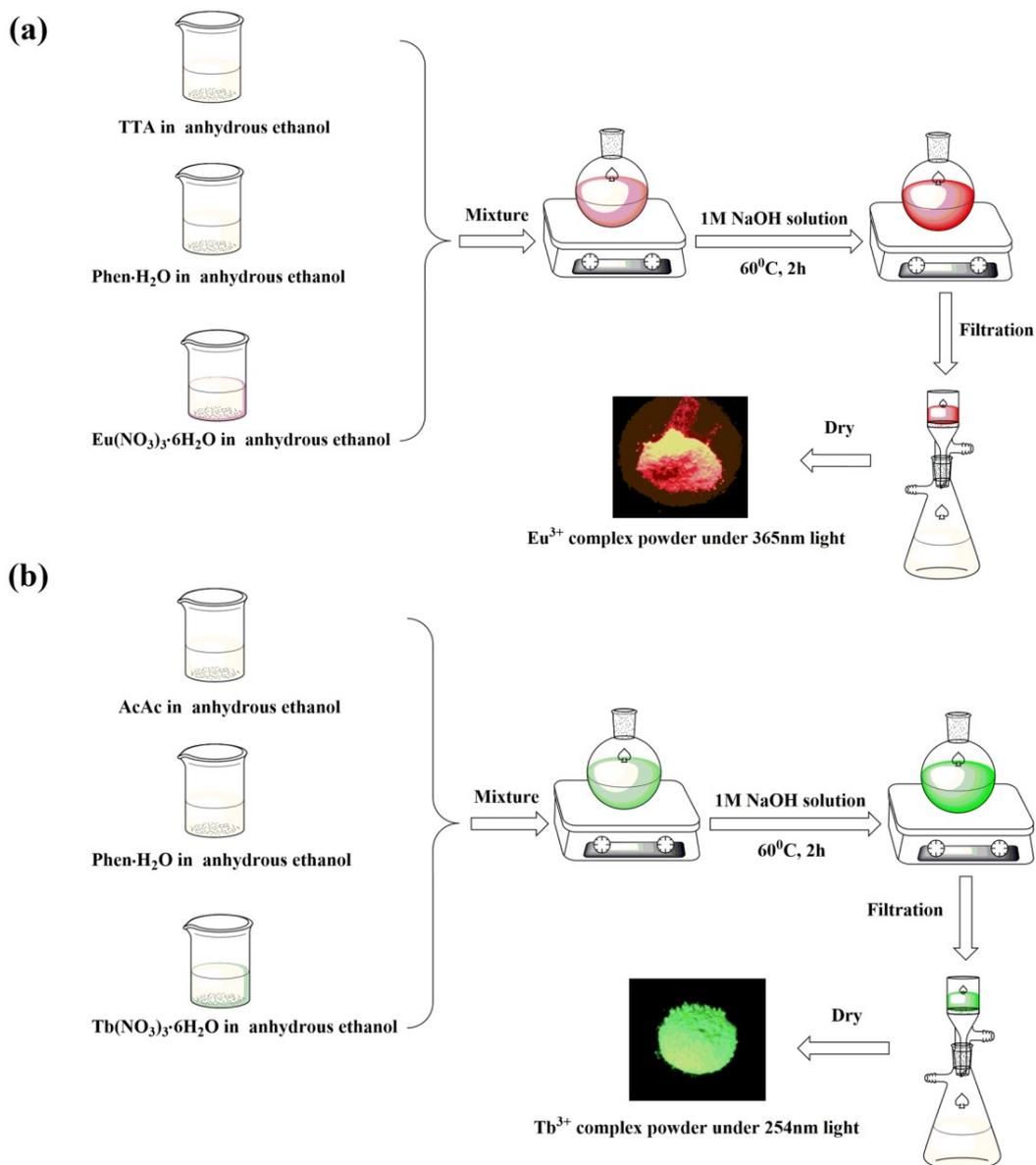


Fig. S1 Synthetic procedure of the Eu³⁺ complex (a) and Tb³⁺ complex (b) and the digital images of the corresponding powder samples under 365 nm or 254 nm UV lights, respectively.

Results and discussion

Characterization of the recycled PS

Fig. S2 shows the FTIR spectrum of the recycled PS. The bands at 3060 cm⁻¹ and 3026 cm⁻¹ are assigned to the stretching vibrations of the C-H band on the benzene ring.

The bands at 2921 cm^{-1} and 2850 cm^{-1} are attributed to the asymmetric stretching vibration and symmetric stretching vibration of the CH_2 group, respectively. The absorption bands at 1601 cm^{-1} , 1493 cm^{-1} and 1450 cm^{-1} are assigned to the bent vibrations of the $\text{C}=\text{C}$ of the benzene ring. The absorption bands at 755 cm^{-1} and 697 cm^{-1} are corresponding to the bent vibrations of the $\text{C}-\text{H}$ of the single substituted benzene ring.

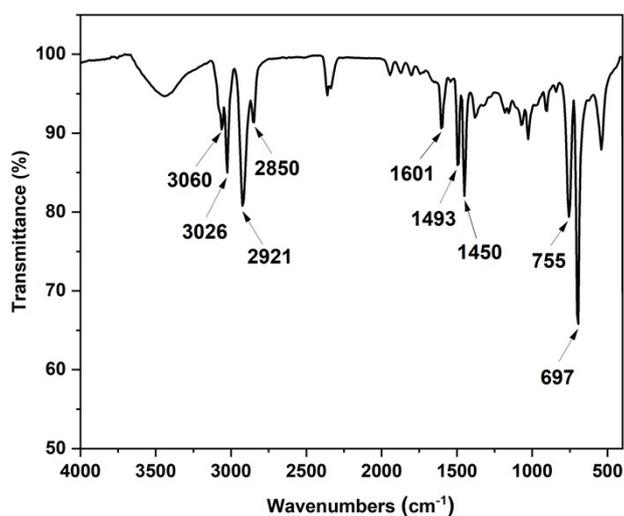


Fig. S2 FTIR spectrum of the recycled PS.

Characterization of the lanthanide complexes

Fig. S3 displays the FTIR spectrum of the as-prepared Eu^{3+} complex, as well as those of the corresponding ligands for comparative analysis. It can be found that the $\text{C}=\text{O}$ and $\text{C}=\text{C}$ stretching vibration bands of TTA shifted from 1655 cm^{-1} and 1584 cm^{-1} in Fig. S3a to 1628 cm^{-1} and 1540 cm^{-1} in Fig. S3c, suggesting the formation of the coordination bonds between the Eu^{3+} ions and TTA.^{1,2} On the other hand, the band corresponding to the $\text{C}=\text{N}$ stretching vibration at 1617 cm^{-1} and the bands corresponding to the $\text{C}-\text{H}$ bent vibrations at 854 and 739 cm^{-1} of Phen in Fig. S3b shifted to 1601 cm^{-1} , 844 cm^{-1} and 728 cm^{-1} , respectively, in Fig. S3c, indicating that Phen also participated in the coordination with the Eu^{3+} ions.^{1,3} The above results prove that both TTA and Phen coordinated with the Eu^{3+} ions in the Eu^{3+} complex.

Fig. S4 presents the FTIR spectrum of the as-prepared Tb^{3+} complex and the

corresponding ligands. The C=O stretching vibration band of the ligand AcAc shifted from 1621 cm^{-1} in Fig. S4a to 1587 cm^{-1} in Fig. S4c, suggesting that AcAc coordinated with the Tb^{3+} ions.^{4,5} Besides, the band corresponding to the C=N stretching vibration at 1617 cm^{-1} and the bands corresponding to the C-H bent vibrations at 854 and 739 cm^{-1} of Phen in Fig. S4b shifted to 1610 cm^{-1} , 850 cm^{-1} and 730 cm^{-1} , respectively, in Fig. S4c, confirming that Phen also coordinated with the Tb^{3+} ions. These results demonstrate that both AcAc and Phen participated in the coordination reaction with the Tb^{3+} ions.

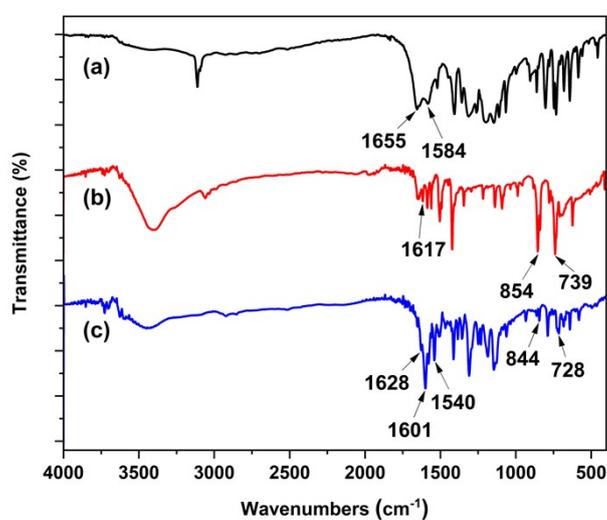


Fig. S3 FTIR spectra of TTA (a), Phen·H₂O (b) and the Eu³⁺ complex (c).

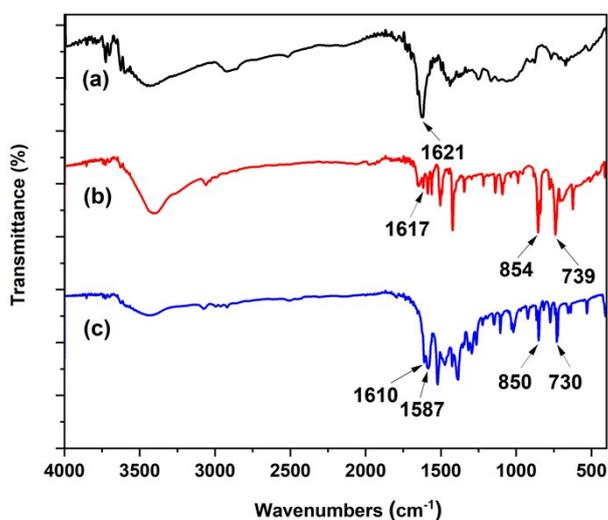


Fig. S4 FTIR spectra of AcAc (a), Phen·H₂O (b) and the Tb³⁺ complex (c).

Notes and references

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