Electronic Supporting Information (ESI)

Electrospun Light Stimulus Response Enhanced Anisotropic Conductive Janus Membrane with Up/Down-conversion Luminescence

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Experiments

Chemicals

Polyethylene glycol (PEG, Mw=20000), methylmethacrylate (MMA), benzoylperoxide (BPO), *N,N*-dimethylformamide (DMF), $CHCl_3$, polyvinylpyrrolidone (PVP, Mw=1300000) and 2,7-dibromo-9-fluorenone (DF), ammonium persulfate (APS), Eu_2O_3 (99.99 %), triphenylphosphine oxide (TPPO), 3-thienylformyltrifluoroacetone (TTA), (1S)-(+)-10-camphorsulfonic acid (CSA), Y_2O_3 (99.99 %), Yb_2O_3 (99.99 %), Tm_2O_3 (99.99 %), polyacrylonitrile (PAN), ethylene glycol (EG), NaF, NH_4F, $NaNO_3$, anhydrous ethanol were used, and all of the chemicals were of analytic grade and purchased from Aladdin reagent Co. LTD, Shanghai, China. Ultrapure water was prepared by Mili-QAdvantageA10 ultrapure water machine in our laboratory.

Construction of spinning liquids

Table S1 Compositions of the spinning liquid I.

Spinning liquid I	PANI/PMMA /wt %	ANI/g	CSA/g	APS/g	DMF/g	CHCl$_3$/g	PMMA/g	DF/g
S$_{a1}$	15	0.09	0.22	0.22	1.8	8.2	0.6	0.12
S$_{a2}$	30	0.18	0.44	0.44	1.8	8.2	0.6	0.12
S$_{a3}$	50	0.30	0.74	0.73	1.8	8.2	0.6	0.12
S$_{a4}$	30	0.18	0.44	0.44	1.8	8.2	0.6	0.18
S$_{a5}$	30	0.18	0.44	0.44	1.8	8.2	0.6	0.24

Table S2 Compositions of the spinning liquid II.

Spinning liquid II	Eu(TTA)$_3$(TPPO)$_2$/ PMMA/wt %	Eu(TTA)$_3$(TPPO)$_2$/g	DNF/g	CHCl$_3$/g	PMMA/g
S$_{b1}$	10	0.10	4.0	12.0	1.0
S$_{b2}$	15	0.15	4.0	12.0	1.0
S$_{b3}$	20	0.20	4.0	12.0	1.0
S$_{b4}$	25	0.25	4.0	12.0	1.0
S$_{b5}$	30	0.30	4.0	12.0	1.0

Table S3 Compositions of the spinning liquid III.

Spinning liquid III	NaYF$_4$:Yb^{3+}, Tm^{3+}/PAN/wt %	NaYF$_4$:Yb^{3+}, Tm^{3+}/g	DMF/g	PAN/g
S$_{c1}$	0.5:1	0.5000	8.8200	1.0000
S$_{c2}$	1:1	1.0000	8.8200	1.0000
S$_{c3}$	2:1	2.0000	8.8200	1.0000

[PANI/DF/PMMA]//[Eu(TTA)$_3$(TPPO)$_2$/PMMA] Janus nanobelts and (NaYF$_4$:Yb^{3+}, Tm^{3+}/PAN) nanofibers were used as the constructive units to prepare the light stimulus response enhanced anisotropic

conductive Janus membrane (named as L-ACJM), the processes for preparing the spinning liquids were as follows. PMMA, CSA and ANI with varying ratios were dispersed in the mixing liquid of $CHCl_3$ and DMF, the mixed liquid was magnatically stirred at ambient temperature for 12 hours (called as liquid A), and APS was dispersed into the DMF and stirred for 1 hour (named as liquid B). Liquid A and liquid B were refrigerated for 25 min at 0 °C. Liquid B was poured into liquid A and the obtained mixture was stirred in an ice-water for 3.5 hours. Then DF was added into the above liquid. Finally, the reaction system was kept at 0 °C for 36 hours to obtain spinning liquid I, and the Table S1 gives the practical components of spinning liquid I (S_a). The color of the spinning liquid I was dark green, which accorded with the characteristics of PANI with emeraldine form. The spinning liquid I was used to prepare the conductive region of the [PANI/DF/PMMA]//[Eu(TTA)$_3$(TPPO)$_2$/PMMA] Janus nanobelt. To fabricate Eu(TTA)$_3$(TPPO)$_2$/PMMA nanobelt as the insulative and red-fluorescent region of the Janus nanobelt, in a typical procedure, Eu(TTA)$_3$(TPPO)$_2$ and PMMA were dispersed into a mixed liquid of DMF and $CHCl_3$ under magnetic stirring for 12 hours to form spinning liquid II, the actual components were shown in Table S2. In order to fabricate NaYF$_4$:Yb^{3+}, Tm^{3+}/PAN nanofibers, PAN and DMF were first mixed and heated at 60 °C until a clear and transparent solution was obtained. After the solution was cooled down to room temperature, NaYF$_4$:Yb^{3+}, Tm^{3+} NPs were dispersed into the mixture of PAN and DMF, and the admixture was magnetically stirred for 5 h to obtain uniform mixture called as spinning liquid III, and the real components were summarized in Table S3. Spinning liquid IV was obtained by mixing spinning liquid I and spinning liquid II in equal proportion, which was used to prepare the comparison samples.
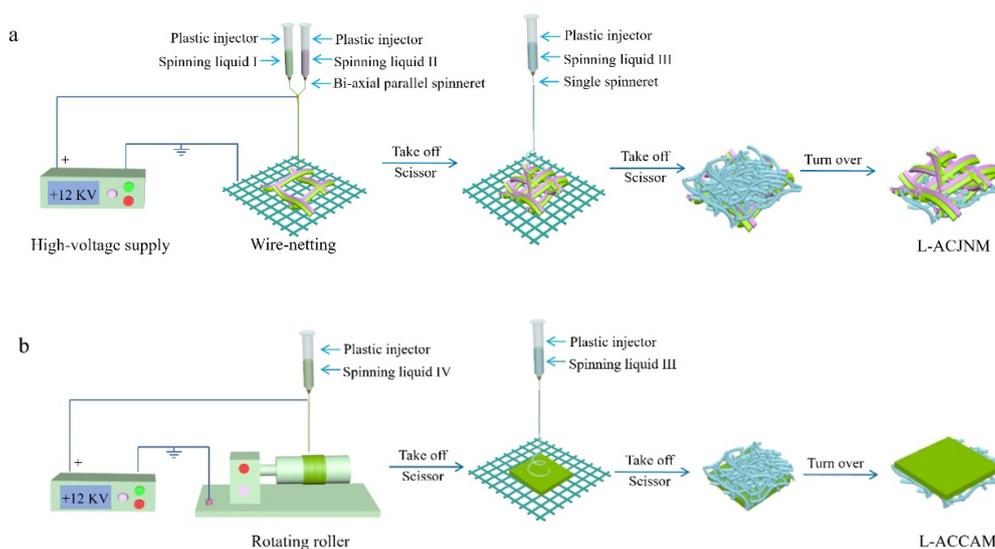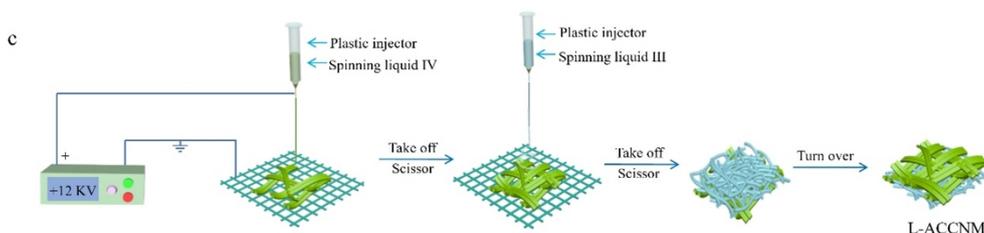
Figure S1 Drawings of electrostatic spinning instruments and for preparing processes

for the three comparison samples.

Characterizations

The energy dispersive spectroscopy (EDS, produced by Oxford Instruments) was used for elemental analyses of the membranes. A scanning electron microscope (SEM, JSM-7610F) and optical microscope (OM, CVM500E) were utilized to observe the morphology and internal structure of the products. The Hitachi fluorescent spectrophotometer F-7000 was utilized to investigate fluorescence properties of the membranes. A xenon lamp and a 980-nm diode laser were respectively used as excitation sources for down-conversion and up-conversion luminescence tests. The emission slit width was fixed at 2.5 nm for down-conversion and up-conversion luminescence, and excitation slit width was fixed at 2.5 nm for down-conversion luminescence. A Hall Effect measurement system (ECOPIA HMS-3000) and a xenon lamp (PLSSXE300/300UV) were applied to measure electrical properties of the products. The x-ray diffractometer (XRD, made by Bruker Corporation) was used to analyse the phase compositions of $NaYF_4$:Yb^{3+}, Tm^{3+} NPs and the prepared samples. Thermogravimetric analyzer (TG, TAQ600) was used to measure the thermal stability of the samples, and the heating rate was kept at 10 °C/min in air. UV-Vis absorbance spectrum of PANI was analyzed on a UV-Vis spectrophotometer (Hitachi U-3010) equipped with an integrating sphere, using $BaSO_4$ as the reference with a wavelength range of 250-800 nm.

Mechanical performance
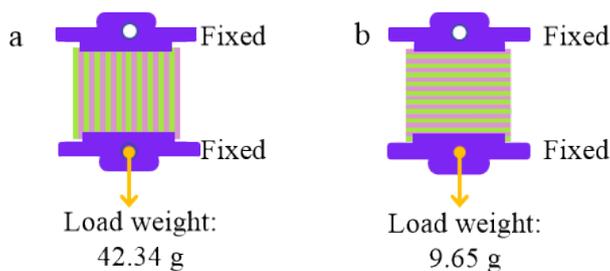
Figure S2 Diagrammatic drawing for fracture strength test of L-ACJM along (a) and perpendicular (b) to

the length direction of Janus nanobelts.

Luminescent performance
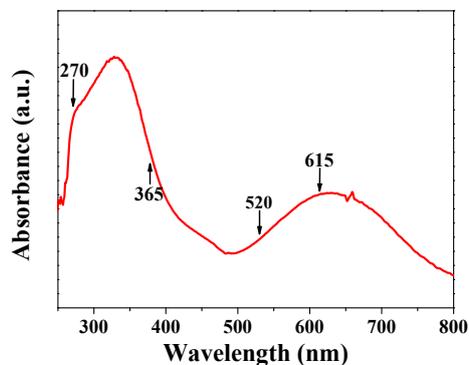
Figure S3 UV-Vis absorbance spectrum of PANI.

Conductive performance

Schematic illustration depicted in Figure S4 is the measurement methods for determining the conductance of the membranes which are tailored to an area of 1×1 cm^2. At the distance of 0.1 cm, two tin sheets with the size of 1×0.45 cm^2 are used as electrodes. Two tin sheets coated with conductive resin, as the electrodes, are respectively pressed on the surface of the samples. Then the two stylets of the Hall effect measurement system are respectively pressed against the two tin sheets.
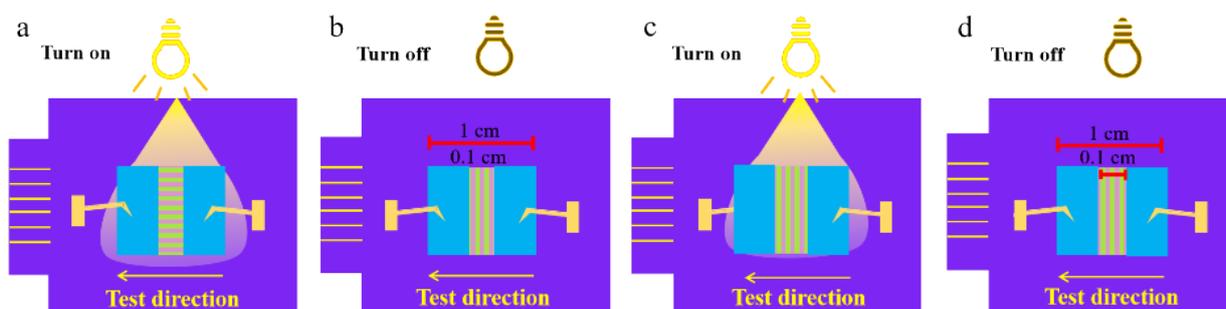
Figure S4 Illustrative drawing for conductance measurement.

Table S4 Photoelectric response of the top layer of the L-ACJM and the three comparison samples at light power density of 1600 mW/cm^2.

Samples	Pc$_A$ (μA)	Dc$_A$ (μA)	Pc$_B$ (μA)	Dc$_B$ (μA)
L-ACJM (PANI:DF:PMMA=1.5:2:10)	0.50	0.16	5.18×10^{-4}	3.77×10^{-4}
L-ACJM (PANI:DF:PMMA=3:2:10)	14.73	6.16	6.25×10^{-4}	6.11×10^{-4}
L-ACJM (PANI:DF:PMMA=5:2:10)	41.07	16.31	7.82×10^{-4}	6.40×10^{-4}
L-ACJM (PANI:DF:PMMA=3:3:10)	15.32	5.18	6.07×10^{-4}	5.60×10^{-4}
L-ACJM (PANI:DF:PMMA=3:4:10)	15.68	4.33	4.11×10^{-4}	2.69×10^{-4}
L-ACJNM (PANI:DF:PMMA=3:2:10)	0.208	0.080	0.232	0.072
L-ACCAM (PANI:DF:PMMA=3:2:10)	0.046	0.021	7.83×10^{-4}	4.82×10^{-4}
L-ACCNM (PANI:DF:PMMA=3:2:10)	0.017	0.010	0.019	0.011

Table S5 Photoelectric response of the L-ACJM at different light power densities.

Light power densities	Pc$_A$ (μA)	Dc$_A$ (μA)	Pc$_B$ (μA)	Dc$_B$ (μA)
1400	12.98	6.08	6.36×10^{-4}	5.95×10^{-4}
1500	13.72	6.07	6.24×10^{-4}	4.74×10^{-4}
1600	14.73	6.16	1.25×10^{-4}	1.11×10^{-4}
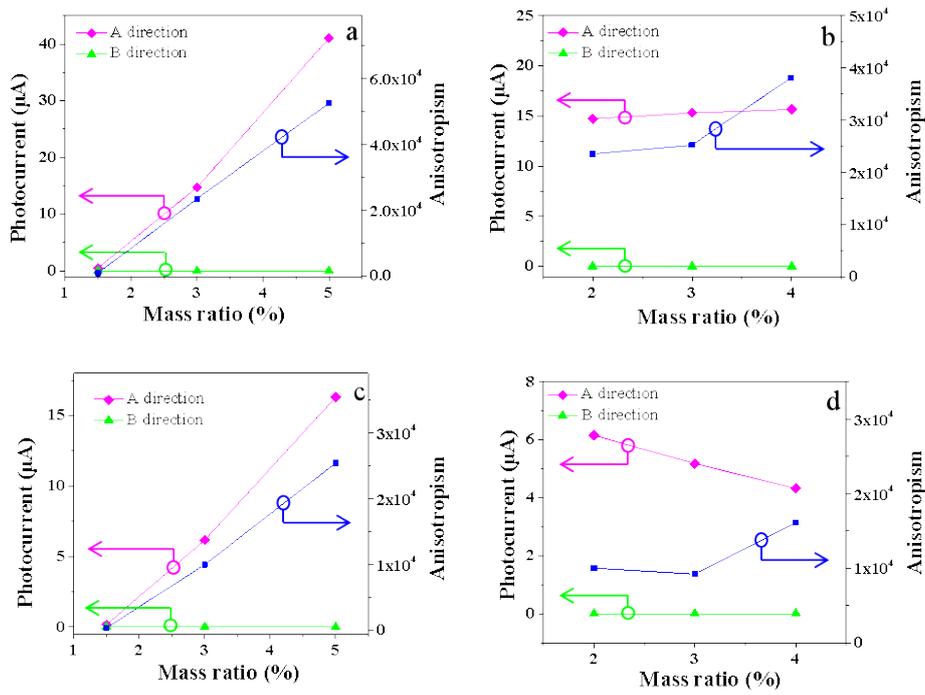
Figure S5 Relationships between the current, the degree of anisotropism and the contents of PANI (a, c)

and DF (b, d) with (a, b) and without (c, d) light illumination.