

Supplementary Materials for **Mechanically Programmable Stretchable Janus Elastomer with Bidirectional Visible-Infrared Radiative Modes for Thermal Regulation and Adaptive Camouflage**

Supplementary Calculations1:

Planck's blackbody radiation law was utilized to calculate the average emissivity of a two-mode membrane over a range of wavelengths. For any object in thermal equilibrium, the spectral absorptivity (α) and emissivity (ε) must be equal according to Kirchhoff's law based on the following equation:

$$\varepsilon = \frac{\int_{\lambda_{min}}^{\lambda_{max}} \varepsilon(\lambda)B(\lambda)d\lambda}{\int_{\lambda_{min}}^{\lambda_{max}} B(\lambda)d\lambda} \quad (1)$$

$$I_{BB}(\lambda) = \frac{c_1\lambda^{-5}}{\exp\left(\frac{c_2}{\lambda T}\right) - 1} \quad (2)$$

$$\varepsilon(\lambda) = \alpha(\lambda) = 1 - R(\lambda) - T(\lambda) \quad (3)$$

Where c_1 is the first radiation constant ($3.7418 \times 10^8 \text{ W} \cdot \mu\text{m}^4 \cdot \text{m}^{-2}$), c_2 is the second radiation constant ($1.4388 \times 10^4 \mu\text{m} \cdot \text{K}$), T is the temperature(K), $R(\lambda)$ is the reflectance at the corresponding wavelength. $\varepsilon(\lambda)$ refers to the emissivity, $\alpha(\lambda)$ is the absorbance, $T(\lambda)$ is the transmittance, the janus membrane is not transparent, so its transmittance $T(\lambda)=0$.

The average solar absorption ratio $\bar{\alpha}$ of the thin membrane surface in the range of 0.3-2.5 μm is determined by:

$$\bar{\alpha} = \frac{\int_{0.3\mu m}^{2.5\mu m} \alpha_{solar}(\lambda, \theta) I_{solar}(\lambda) d\lambda}{\int_{0.3\mu m}^{2.5\mu m} I_{solar}(\lambda) d\lambda} \quad (4)$$

Where λ represents the wavelength of incident light within the range of 0.3-2.5 μm , and $I_{solar}(\lambda)$ is the standardized ASTM G173 global solar intensity spectrum.

Supplementary Table:

Table S1. Comparison Table with Similar Studies.

Material system	Visible Light + Emissivity Tunable Mode	Adjustment Mode Number	Actuation	Ref.
PANI-based	Continuously	N+	Electrical	1
VO ₂ Phase-change	Continuously+Discretely	2	Thermal	2
SEBS/Au film	Discretely	3	Strain/Flip	3
PCMRC	Discretely	2	Flip	4
PDMS NFs	Continuously	2	Strain	5
TPU@LM	Continuously	2	Strain	6
LM@GN/ANF	Discretely	2	Manual/Flip	7
Janus LM/Au	Continuously+Discretely	4	Strain/Manual/Flip	This Work

Table S2. Optical appearance and IR emissivity states of the Janus elastomeric membrane.

Surface(Side)	Mechanical State	Visible Appearance	Emissivity Behavior
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Ecoflex/LM	Relaxed	gray	High
Ecoflex/LM	Stretched	Bright silver-gray	Low
Au	Relaxed	Bright golden	Low
Au	Stretched	Dimmed gold	High

Supplementary Figure:

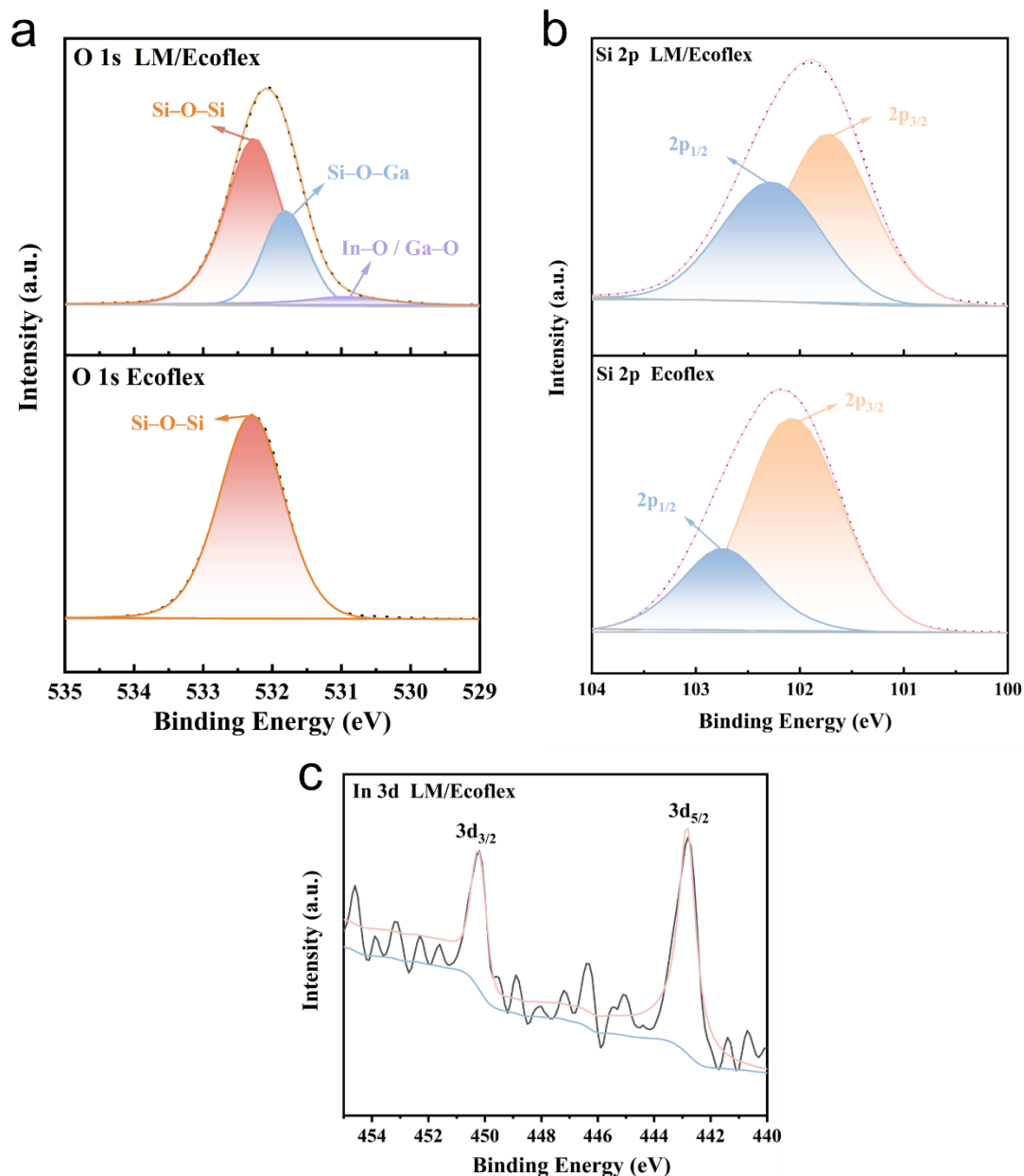


Figure S1. XPS (a) O 1s, (b) Si 2p and (c) In 3d spectra of Janus films.

As shown in Supplementary Fig. S1(a), the O 1s spectrum reveals a distinct intermediate peak at approximately 531.8 eV, in addition to the main Si-O-Si peak of Ecoflex (~532.3 eV) and the native oxide peak of EGaIn (~530.8 eV). This intermediate peak corresponds to the characteristic binding energy of the Si-O-metal (In/Ga) bond, indicating clear interfacial interaction between the siloxane backbone and the oxide surface layer of the liquid metal. The In 3d_{5/2} peak position (442.8 eV, Fig. S1b) is shifted to lower binding energies compared to both metallic In and In₂O₃ references, confirming a chemical interaction at the LM-substrate interface. Consistent with the In 3d and O 1s data, compared with pristine Ecoflex (Si 2p_{3/2} ~102.3 eV, Fig. S1c), the LM/Ecoflex composite also

shows a shift toward lower binding energy (Si 2p_{3/2} ~101.8 eV). This change in the signal from the polymer backbone confirms that the electronic perturbation from the EGaIn droplets extends to the siloxane chains, reinforcing the conclusion of a chemically coupled interface.

In summary, the newly formed bridging O 1s peak, along with the corresponding shifts in In 3d and Si 2p, collectively demonstrate the formation of an interface with enhanced cross-linking between EGaIn and the Ecoflex substrate. These chemically mediated interactions contribute to improved structural stability and optical consistency of the composite under repeated stretching, laying the foundation for reliable strain-dependent emissivity modulation.

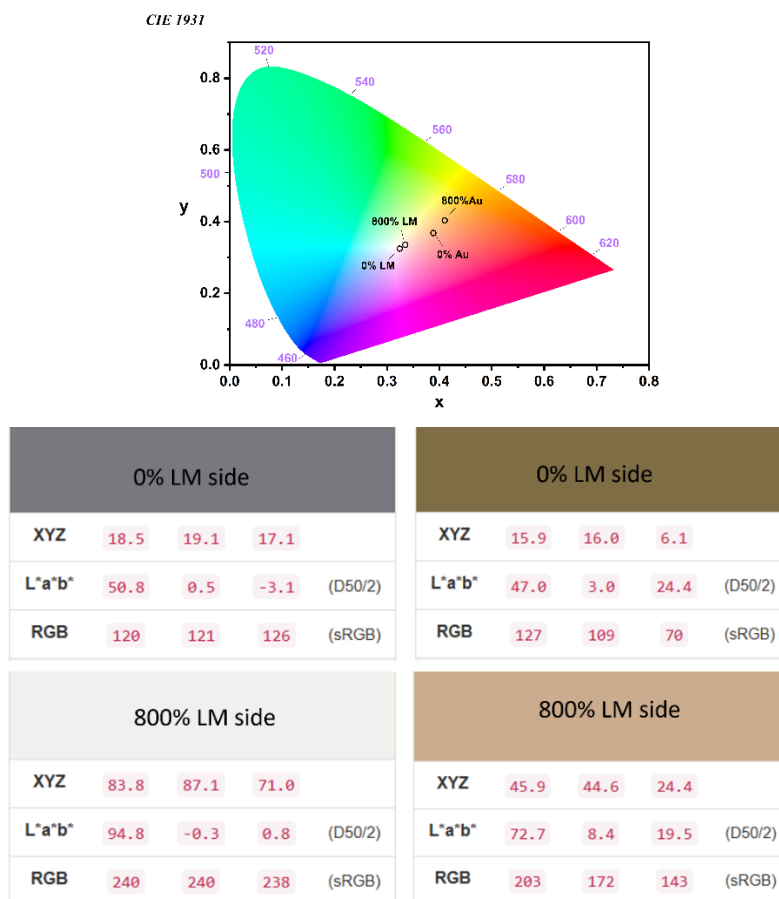


Figure S2. CIE chromaticity coordinates of film colors corresponding to different states.

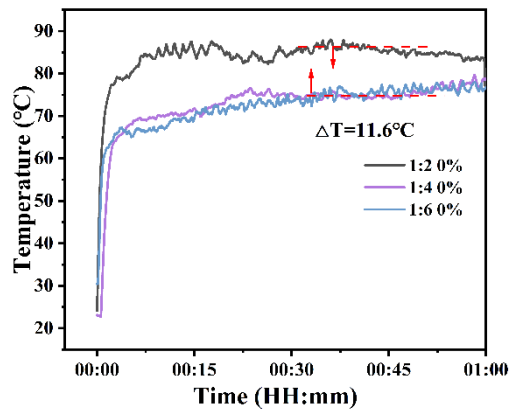


Figure S3. Different LM dosage ratios for thin film Ecoflex/LM side xenon lamp irradiation temperature.

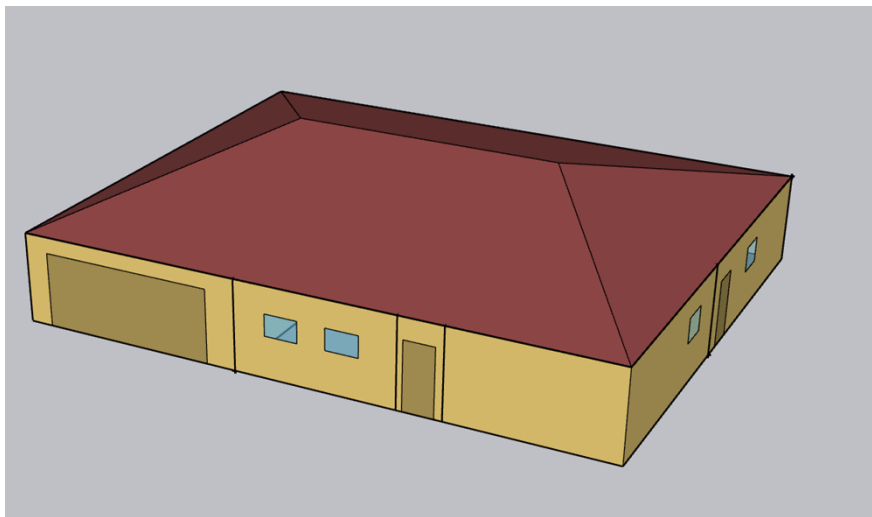


Figure S4. Architectural simulation model dimensions: $20 \times 16 \times 3.05$ m (L \times W \times H), featuring roof height 2.02m.



Figure S5. Flame exposure test of the Janus film.

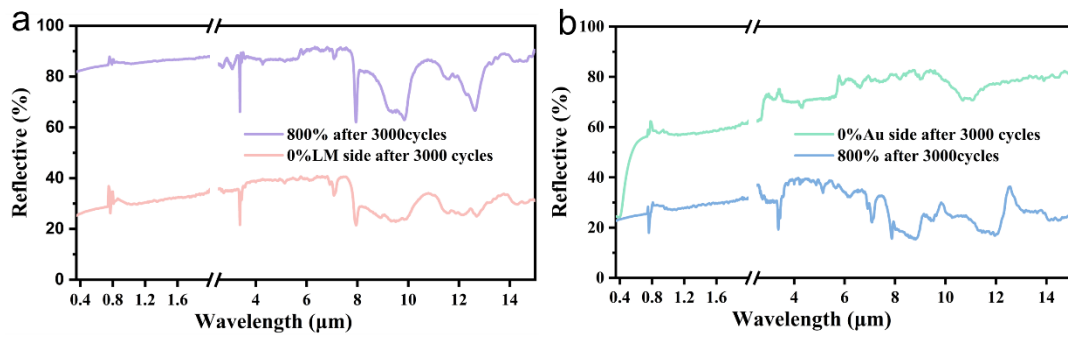


Figure S6. Reflectance graph after 3000 stretching cycles.

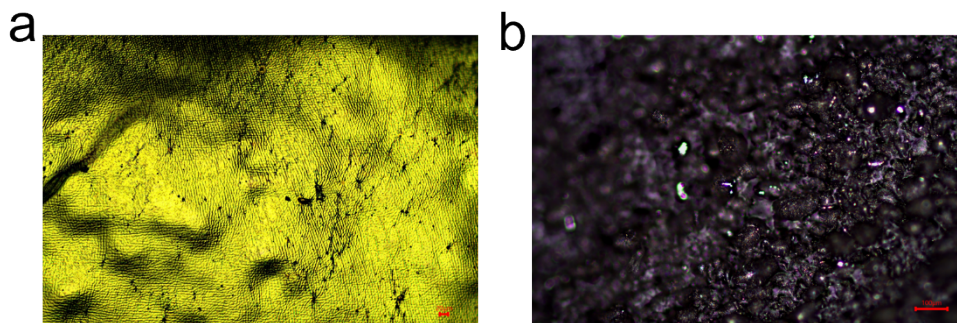


Figure S7. Optical image after 3000 stretching cycles, (a)Au side; (b)LM side.

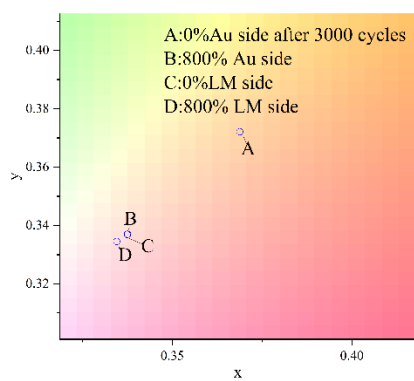


Figure S8. Enlarged CIE chromaticity coordinates of the film in different states after cycling.

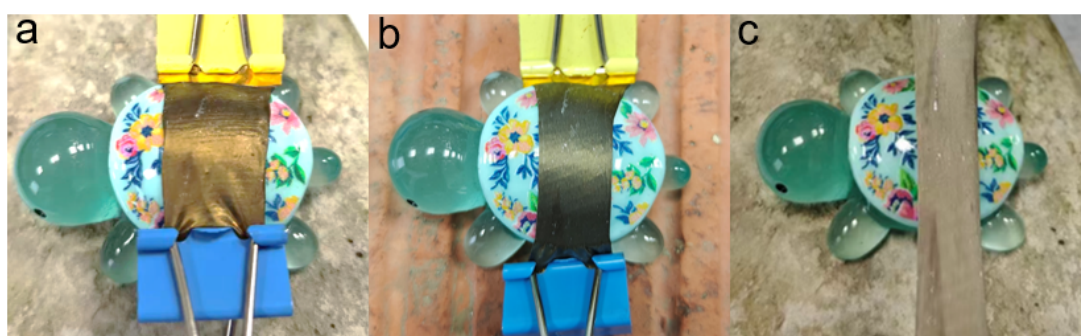


Figure S9. Visible light color changes occur at different tensile strains on the Au side.



Figure S10. Simulating proximity to a heat source with the palm, infrared reflection occurs on the Au side.

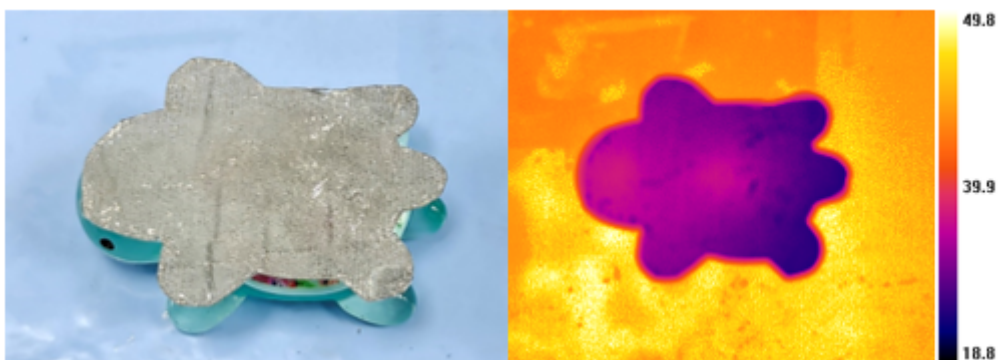


Figure S11. Elastomers can be customized as decoys.

Reference

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