

Photonic structure arrays generated using butterfly wing scales as biological units

Supporting Information

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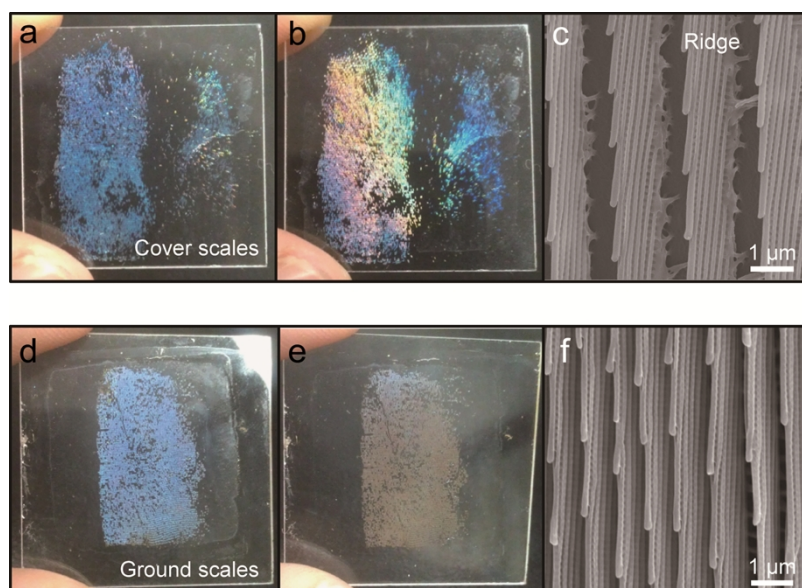
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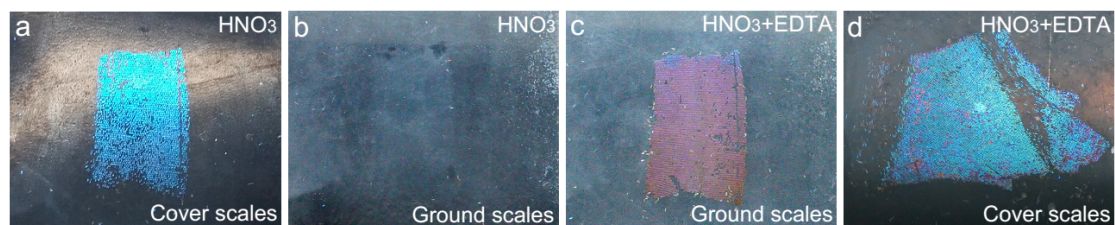
1. *Differences between two kinds of PSAs on quartz substrates. (Supp. Fig. 1)*
2. *Comparison of the attachment ability of various scales on the same kind of latex membrane. (Supp. Fig. 2)*
3. *Necessity of the formation of chemical bonds during the immobilization process. (Supp. Fig. 3)*
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1. *Differences between two kinds of PSAs on quartz substrates.*



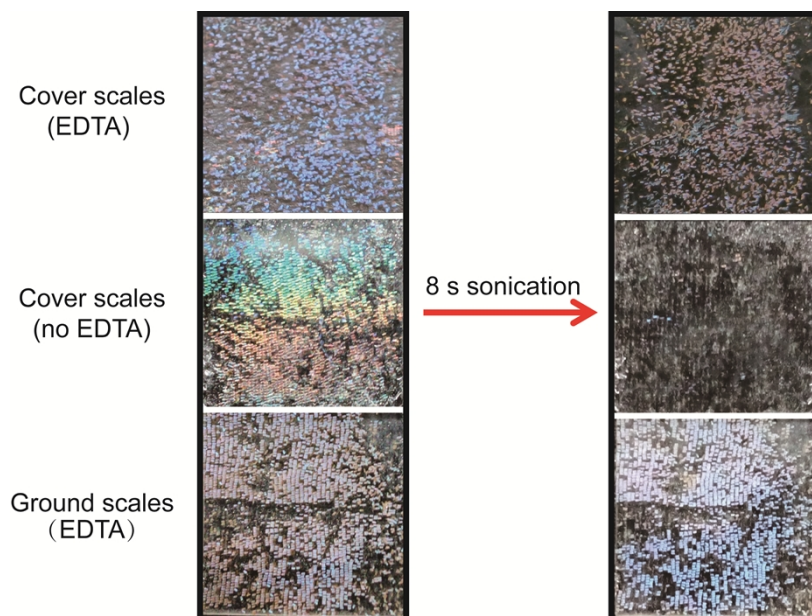
Supp. Fig. 1 Differences between two kinds of PSAs on quartz substrates ($\sim 3\text{ cm} \times 3\text{ cm}$) showing the necessity of the scale-separation process shown in Scheme 1(b) in the main text. (a–c) PSAs formed by the cover scales of *M. menelaus*. (a–b) Color of the PSAs changed from blue to iridescence with the substrate tilted in a small angle. (c) SEM image of the cover scales. (d–f) PSAs composed of ground scales. (d–e) Color of the PSAs changed from bright blue to brown with the substrate tilted in a small angle. (f) SEM image of the ground scales. Though ground scales have similar ridge structures as cover scales have, they contain pigments that absorbed most visible lights except the blue one. Detailed analyses of the angle-dependent optical properties for these two kinds of scales can be found in previous literatures.^{1,2}

2. *Comparison of the attachment ability of various scales on the same kind of latex membrane.*



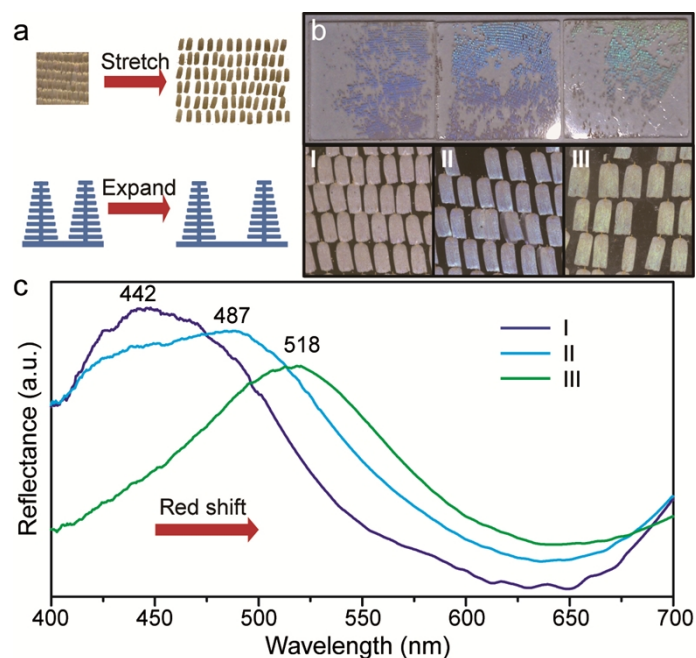
Supp. Fig. 2 Comparison of the attachment ability of various scales on the same kind of latex membrane. (a) and (b) indicate that even experiencing the HNO₃ treatment, ground scales (b) still cannot be transferred onto the latex membrane while cover scales (a) can. (c) demonstrates that after the HNO₃ and EDTA treatment, ground scales with more –COOH groups than (b) can thus be successfully transferred. (d) shows the cover scales transferred onto the latex membrane via HNO₃ plus EDTA treatment.

3. *Necessity of the formation of chemical bonds during the immobilization process.*



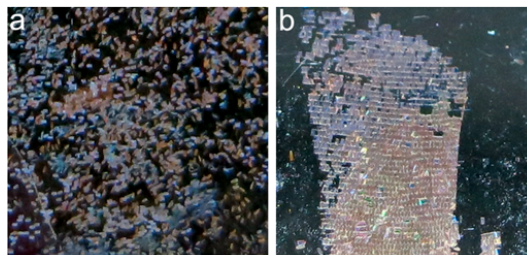
Supp. Fig. 3 Necessity of the formation of chemical bonds during the immobilization process. Three PSAs made of cover scales and ground scales on quartz substrate were sonicated under 40 kHz with a power output of 240 W, respectively. After 8 seconds, a great number of cover scales without the EDTA treatment detached from the quartz substrate, while the scales treated with EDTA were well-kept. Therefore, the binding between the EDTA-treated scales and the quartz substrate is much stronger than its counterpart without the EDTA treatment. This result is consistent with our discussion that scales formed chemical bonds with quartz substrates, while the link between cover scales without EDTA treatment and quartz substrates remained as molecular interactions.

4. Reflectance change of biological PSAs with the stretching of latex membrane.



Supp. Fig. 4 Reflectance change of biological PSAs with the stretching of latex membrane. (a) Hypothetical mechanism of the color change with the membrane stretching.^{3,4} (b) Color changes of PSAs with the stretching of latex membranes. (c) Reflectance spectra of biological photonic units under the same light incidence condition using a clean quartz substrate as reference. Detailed studies on this phenomenon are still under way at present.

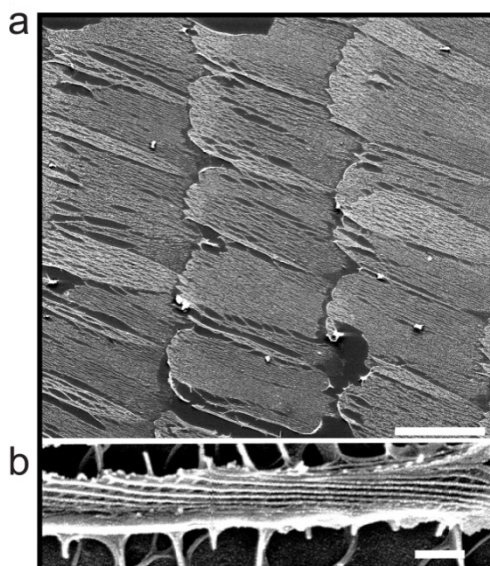
5. *PSAs immobilized on silicon wafers.*



Supp. Fig. 5 Two kinds of PSAs immobilized on silicon wafers. (a) Cover scales and (b) ground scales. The silicon wafers were pre-treated and functionalized via the same processes as the quartz substrates experienced.

6. ZnO PSAs.

ZnO PSAs were generated following a modified replication process reported in Ref. 5. A quartz substrate with scale arrays immobilized upon was first carefully dipped into a closed vessel containing a saturated solution of $\text{Zn}(\text{NO}_3)_2$ in ethanol and kept for 12 h at room temperature. After that, the quartz substrate was rinsed in deionized water for 5 min to remove the redundant solutes on the PSAs and subsequently dried in air at room temperature. The specimen was then placed into an oven and heated up to 500°C with a heating rate of 1°C min^{-1} . By being kept at 500°C for 2 h, the chitin substrates were burned off, yielding ZnO PSAs. Finally, the furnace cooled down naturally to room temperature, which took about 36 h, and the ZnO butterfly wing scale arrays were thus obtained.



Supp. Fig. 6 SEM images of ZnO PSAs under (a) low magnification and (b) high magnification. Scale bars: (a) $100\ \mu\text{m}$ and (b) $500\ \text{nm}$.

References

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