Multi-level Micro-/Nanostructures of Butterfly Wing Adapt Low Temperature to Water Repellency

Supporting Information:

Figure S1 **a**, Photo of *Morpho nestira* butterfly wings with light blue color. **b**, ESEM image of the ridge stacked with six-layer lamellae. The ends of lamellae are of the tilted-up nano-tips in periodicity of ~ 1.5 μm, and running toward the RO direction (indicates with yellow arrow), thus they form the nano-level step topologies on the top of each ridge. Each step between lamella-lamella is ~ 270 nm in height and the lamellas are connected with microrib to contribute the much more porosity. **c,** Butterfly wing composed of the overlapping scales including the top scale and ground scale. The orange arrow indicates the top scale; the yellow arrow indicates the ground scale in (c). **d,** The ground scale of butterfly wing composed of the close structure similar to the top scale.

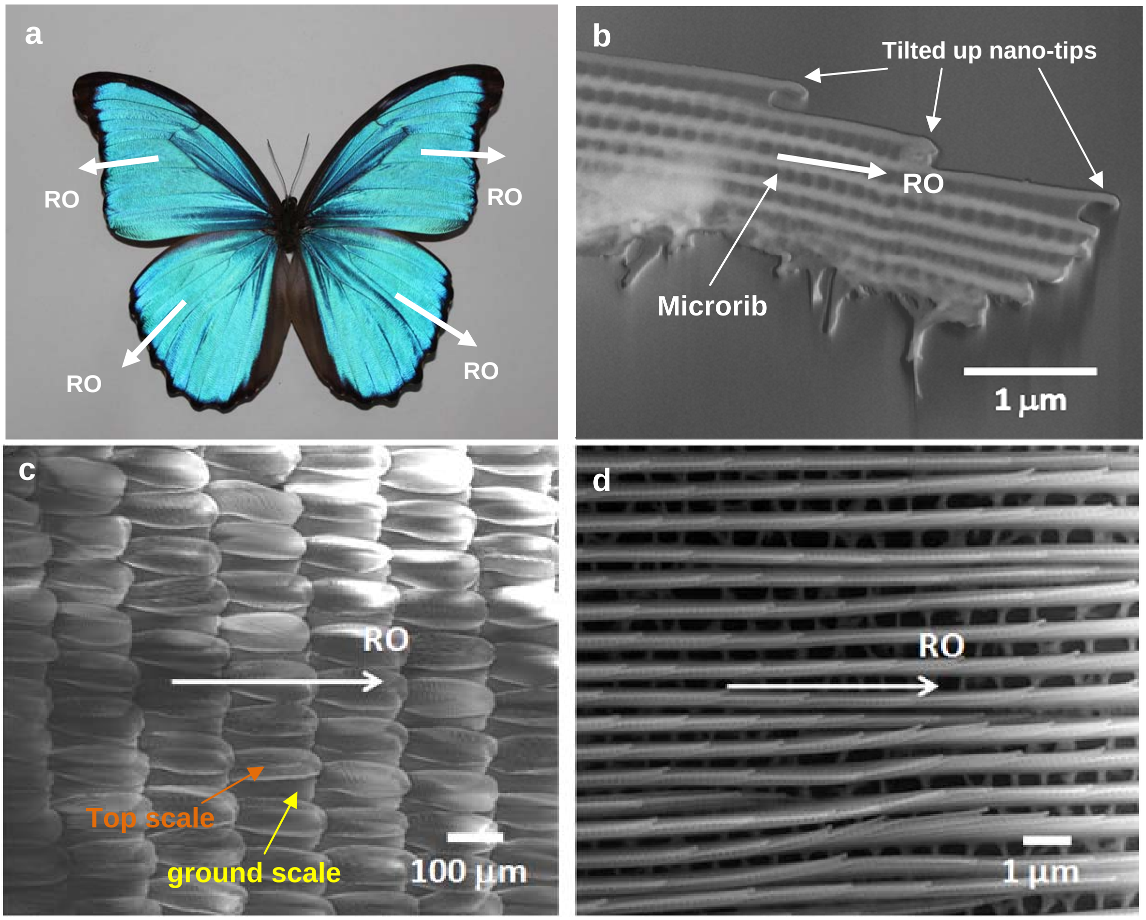

Figure S2. Proflies of drops on butterfly wings under temperature changed from 100°C to -10°C in relative humidity of <10%. The drops are suspended and the tiny water condensed drops are not distinctly observed on the surfaces.

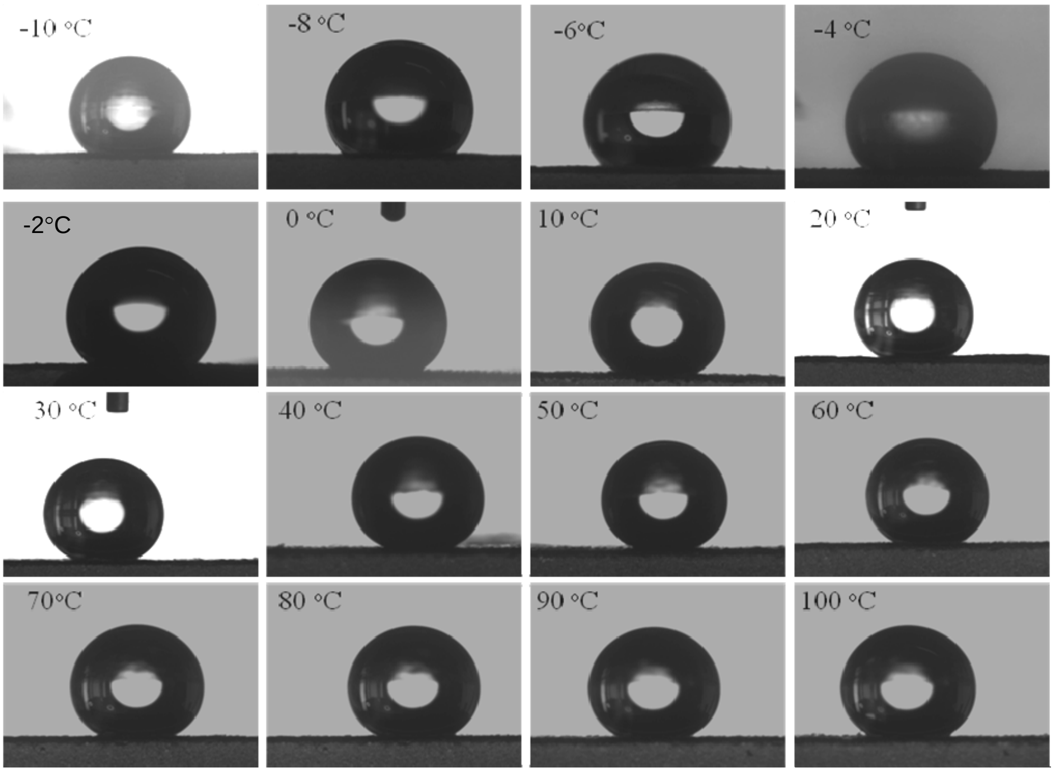

Figure S3. Proflies of drops on butterfly wings under temperature changed from 100°C to -10°C, at intermidiate relative humidity of 40%. The drops are suspended and the tiny water condensed drops are not distinctly observed on the surfaces.

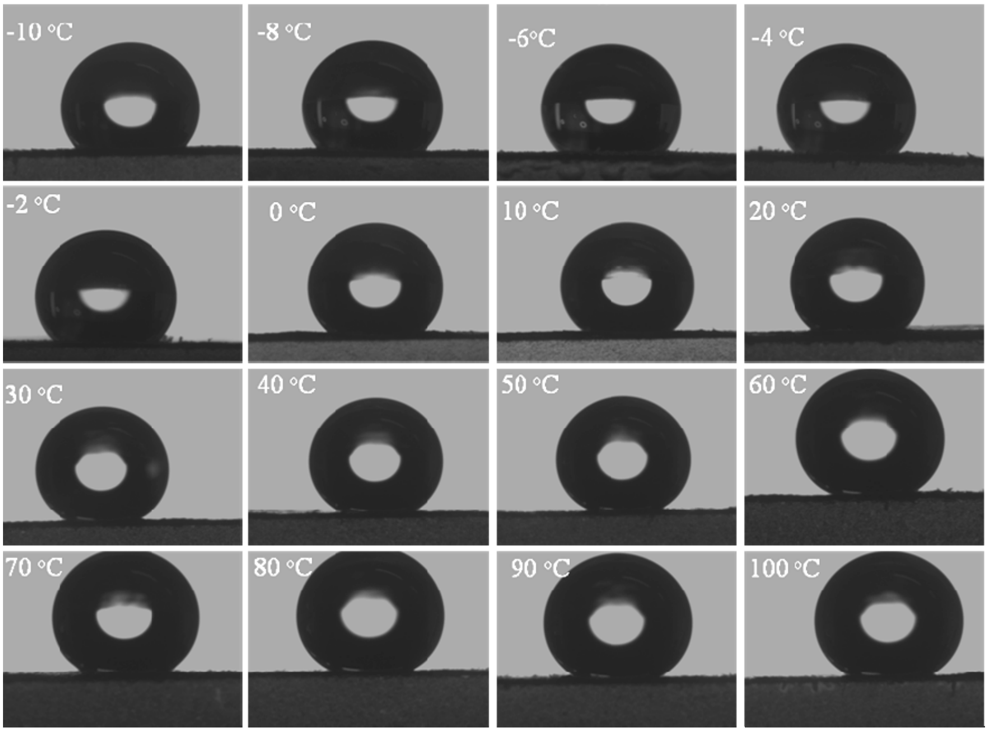

Figure S4. Proflies of drops on butterfly wings under temperature changed from -7°C to 100°C in high relative humidity of > 90%. The drops collapse and the tiny condensed drops are observed on the surfaces in the temperature below zero.

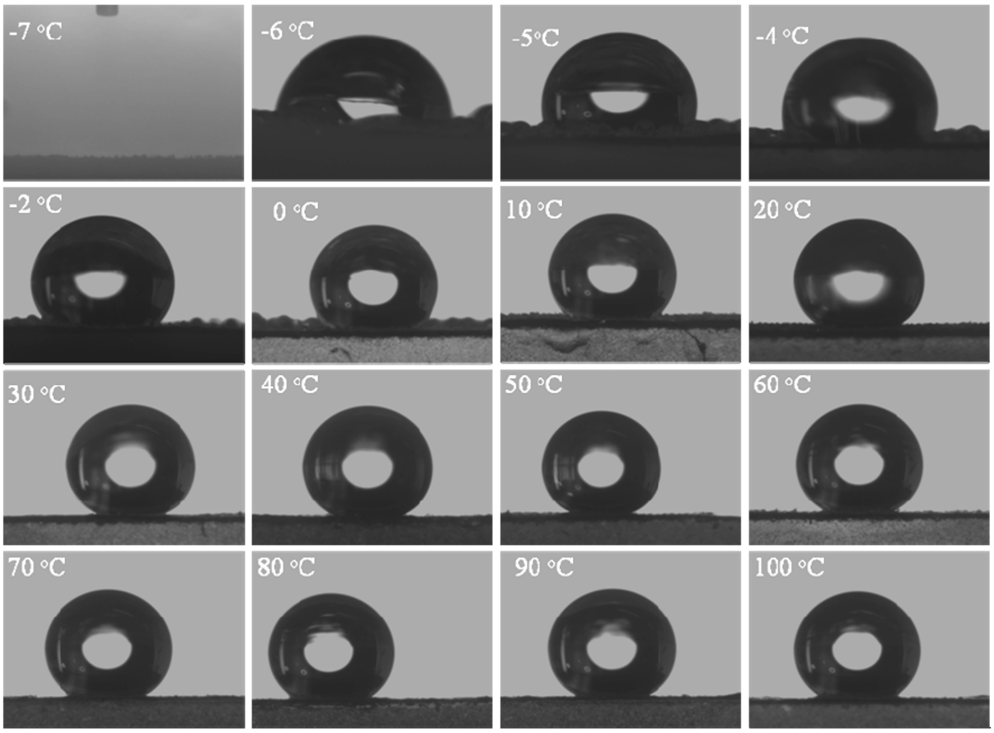

Figure S5 Drops with different volume (5 μl, 10 μl and 15 μl) roll off the surface of butterfly wings under different temperature (from -4 °C to 10 °C) along the RO direction. It indicates the drops (> 10μl) can roll off easily along the RO direction even at T~ -4 °C.

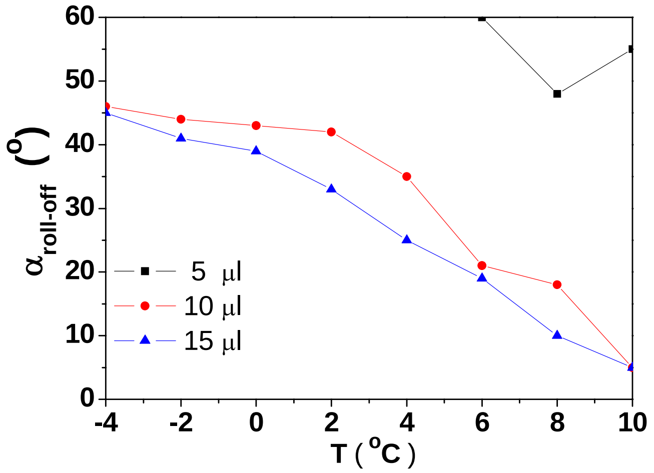

Figure S6 Estimation on trapped-air in micro-/nanostructure of *Morpho nestira* butterfly wing. According to the Cassie-Baxter equation, $\cos\theta = f(\cos\theta_0 + 1) - 1$, where f is the fraction of solid-liquid, the trapped-air is valued by 1−f; θ_0 is the contact angle of smooth surface. The enough larger value (1−f) would reduce greatly surface contact with water, accordingly, result in a superhydrophobic property. Based on the observed data by ESEM (Fig. 1), the top scales of wing are considered mainly, we estimate that the structured surface of butterfly wing provides the solid fraction (f) of ~ 3.6 %, which can be valued by $f = f_1 \times f_2$ based on ESEM observation on the surface feature of micro-/nano-striped structure (where f_1 is the micro-level solid fraction $f_1 \approx W/P$; f_2 is the nano-level solid fraction, $f_2 \approx m/n$). The micro-/nanostructure with trapped-air ratio of more than 96.4 % favors to retard the decreasing of water contact angles under low temperature.