Supporting Information

Achieve structural white inspired from quasi-ordered microstructures in *Morpho theseus*

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Content:

Other Supporting Information for this manuscript include the following:

Supplementary Text

Model characterization of tubular structure:

As shown in Fig. S2a, S_{tub} is twice the distance between x_1 and x_2. The expression for x_2 is

$$x_{h2} = \frac{T_h}{2\pi} \cdot \sin^{-1} a_h \tag{1}$$

S_{tub} is given by:

$$S_{tub} = 2 \cdot \left(x_2 - x_1 \right) = \left(\frac{1}{2} - \frac{1}{\pi} \cdot \sin^{-1} a_{tub} \right) \cdot T_{tub} \tag{2}$$

D_{tub} is given by:

$$D_{tub} = \sqrt{\left(\frac{T_{tub}}{2} \right)^2 + \left(\frac{T_{tub}}{2} \right)^2} = \frac{\sqrt{2} T_{tub}}{2} \tag{3}$$

As shown in Fig. S2b, there is a negative correlation between S_{tub} and a_{tub}.

Numerical characterization of tubular structure in omni direction:

As mentioned in main text, the tubular structures in *Morpho theseus* scales are distributed in omni direction. This feature can be understood as the rotation of the structure in mathematics. Take the tubular structure at state of (0, 1, 0) as example, the orientation of the tubes is along the *x* direction. Here we introduce the rotation elements $k_1 \cdot x$ and $k_2 \cdot x$ in *y* and *z* respectively as

$$\sin\left[\frac{2\pi}{T} \left(y + k_1 \cdot x \right) \right] \cdot \cos\left[\frac{2\pi}{T} \left(z + k_2 \cdot x \right) \right] = t \left(t \geq a \right) \tag{4}$$

As factor k_1 increases, the structure rotates in XY plane while tubes rotate in XZ plane with k_2 increasing. The schematic diagram is shown in Figure S8.

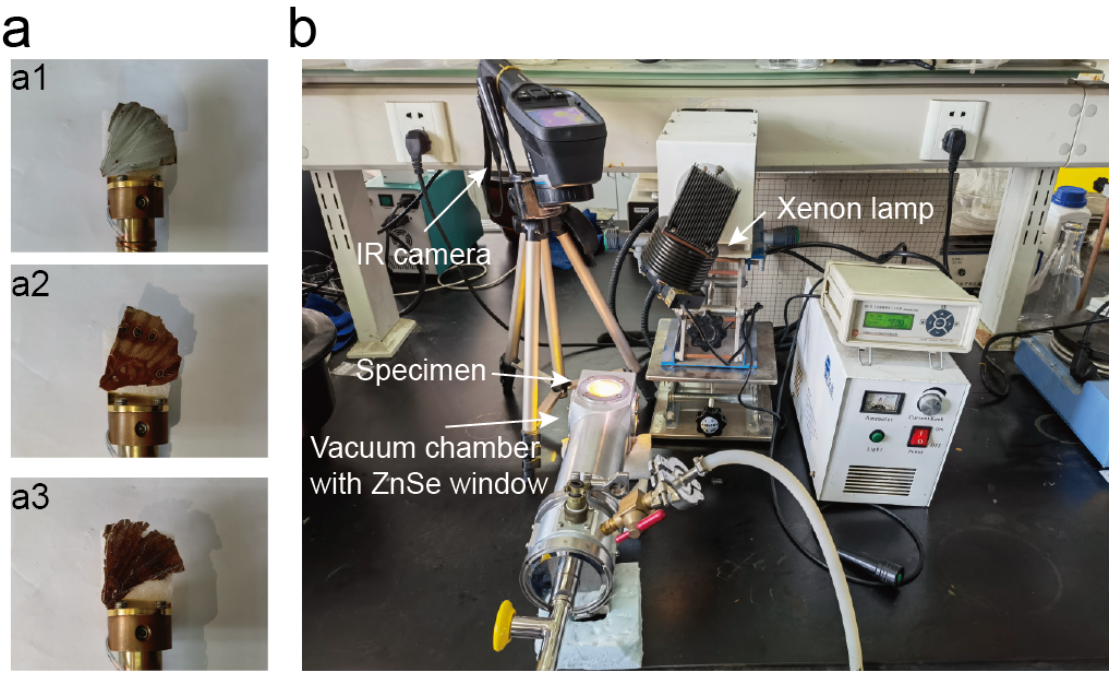

Fig. S1 Photos of thermodynamic experimental specimens and setup. a Photos of *M. theseus* wings of (a1) ventral side, (a2) dorsal side, and (a3) ventral side with scales removed. **b** Photo of experimental setup.

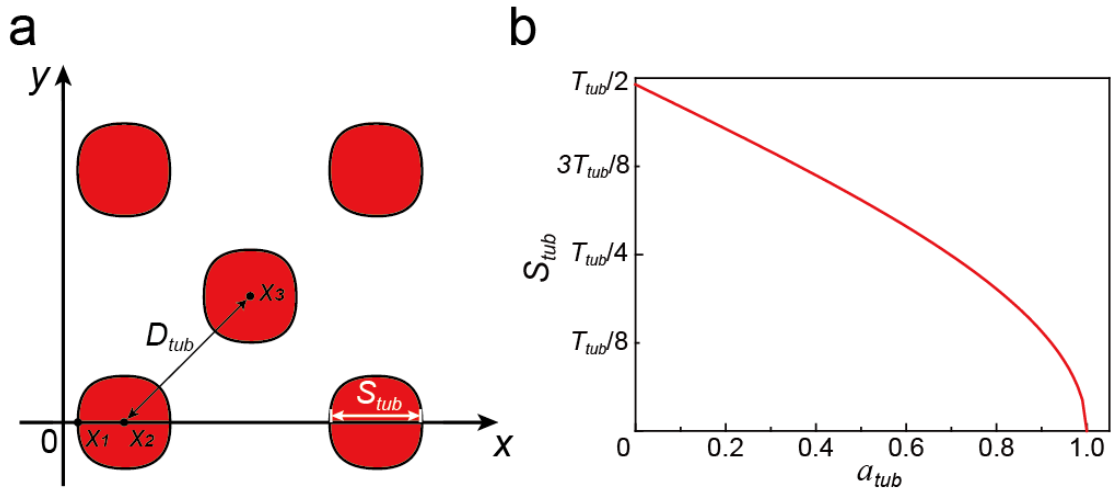

Fig. S2 Tubular structure detailed parameters. a Tubular structure parameters. **b** S_{tub} versus a_{tub}.

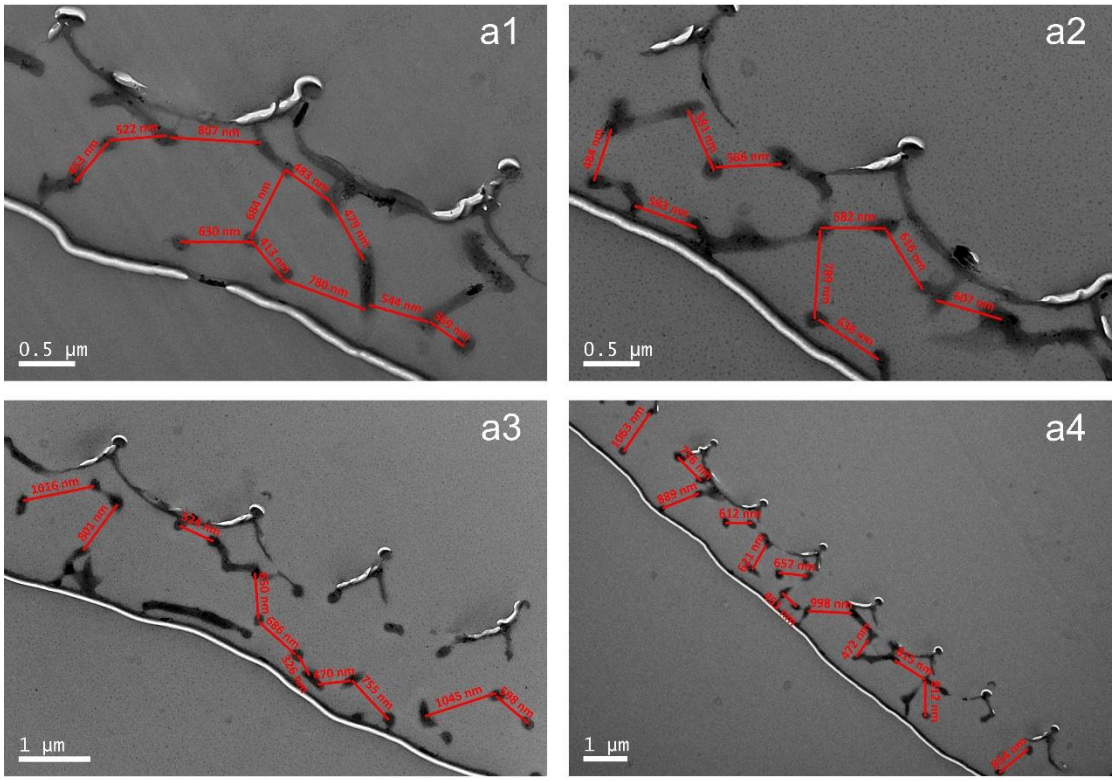

Fig. S3 Periods information measured from TEM images.

Table S1 Periods statistics acquired from Fig. S3.

	a1	a2	a3	a4
Period (nm)	453 522 807 630 684 483 413 479 780 544 369	484 581 586 583 582 789 616 636 607	1016 801 524 650 686 326 470 755 1045 598	1063 756 889 612 621 657 451 998 472 815 812 854
Range (nm): [326, 1063]		Average (nm): 654.74		

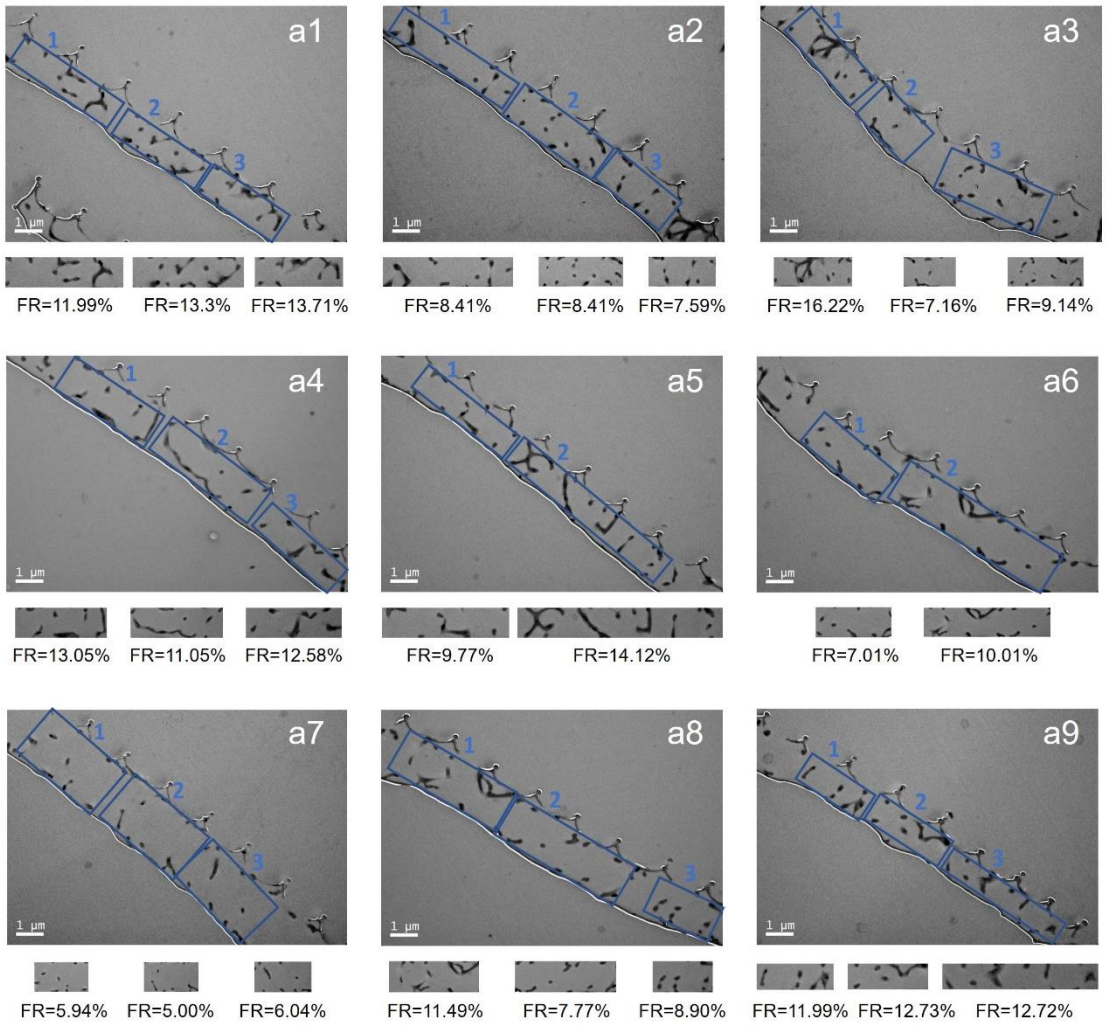

Fig. S4 Volume fractions information measured from TEM images.

Table S2 Volume fractions statistics acquired from Fig. S4.

	Volume fraction		
	1	2	3
a1	11.99%	13.3%	13.71%
a2	8.41%	8.41%	7.59%
a3	16.22%	7.16%	9.14%
a4	13.05%	11.05%	12.58%
a5	9.77%	14.12%	——
a6	7.01%	10.01%	——
a7	5.94%	5.00%	6.04%
a8	11.49%	7.77%	8.90%
a9	11.99%	12.73%	12.72%
Range: [5.00%, 16.22%]		Average: 10.24%	

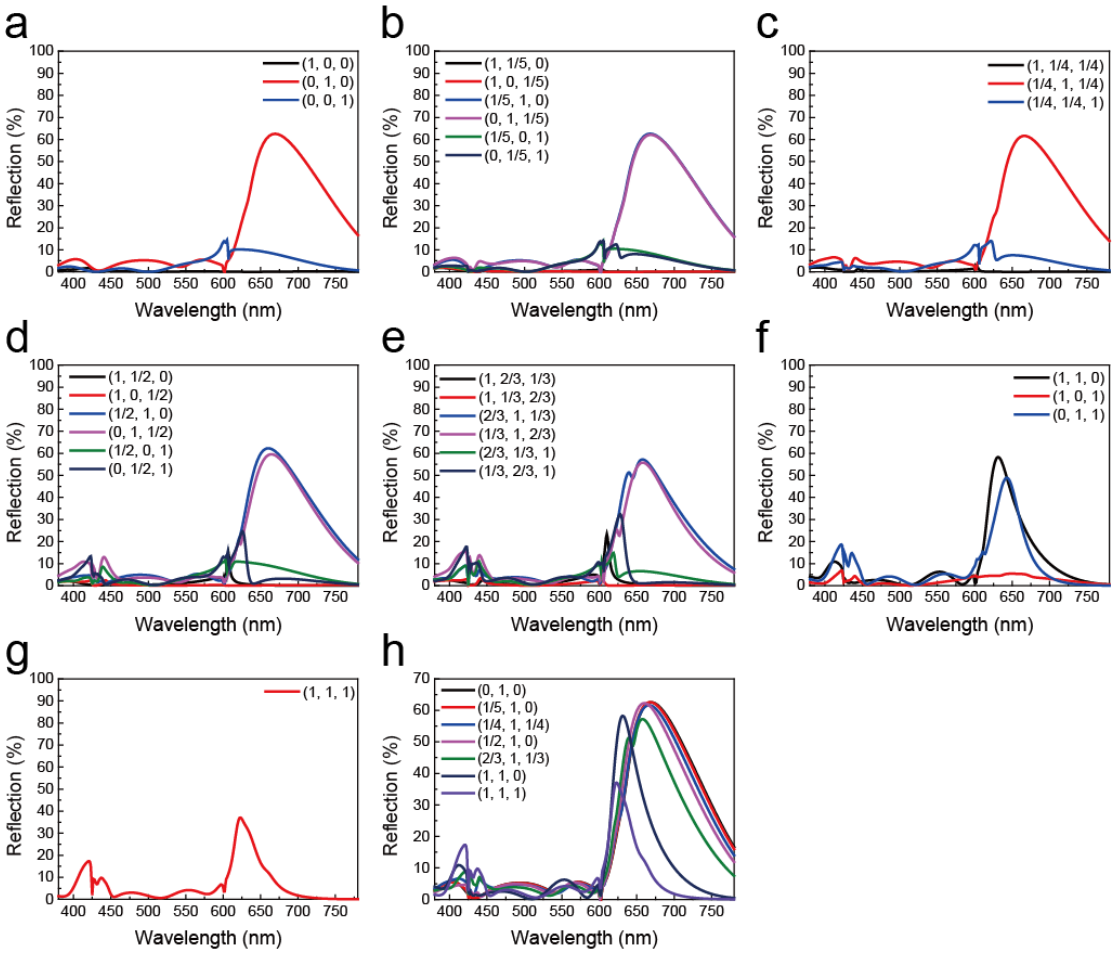

Fig. S5 Optical response under different morphologies. a-g Reflection spectra under different orientations at states (1, 0, 0), (1, 1/5, 0), (1, 1/4, 1/4), (1, 1/2, 0), (1, 2/3, 1/3), (1, 1, 0), and (1, 1, 1). **h** Reflection spectra under different degrees of tubular spiraling.

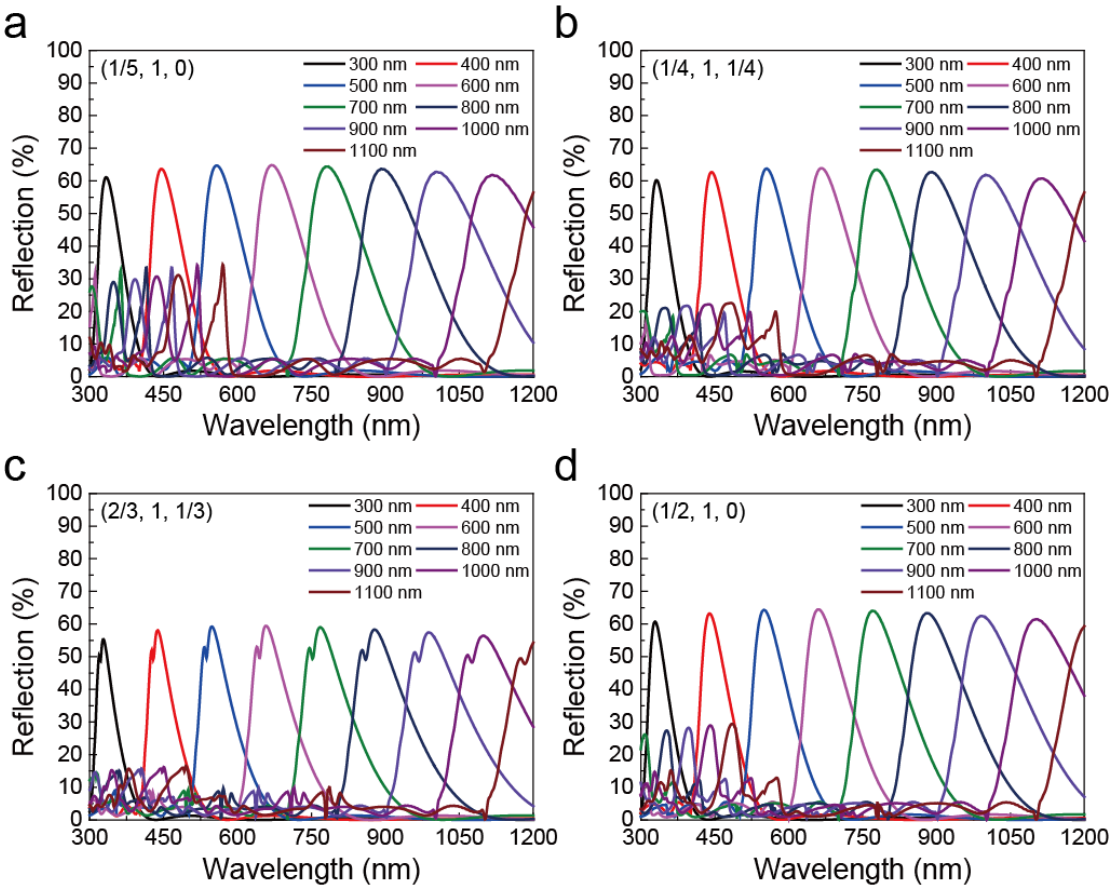

Fig. S6 Optical response under different periods. Reflection spectra at states **a** (1/5, 1, 0), **b** (1/4, 1, 1/4), **c** (2/3, 1, 1/3), and **d** (1/2, 1, 0).

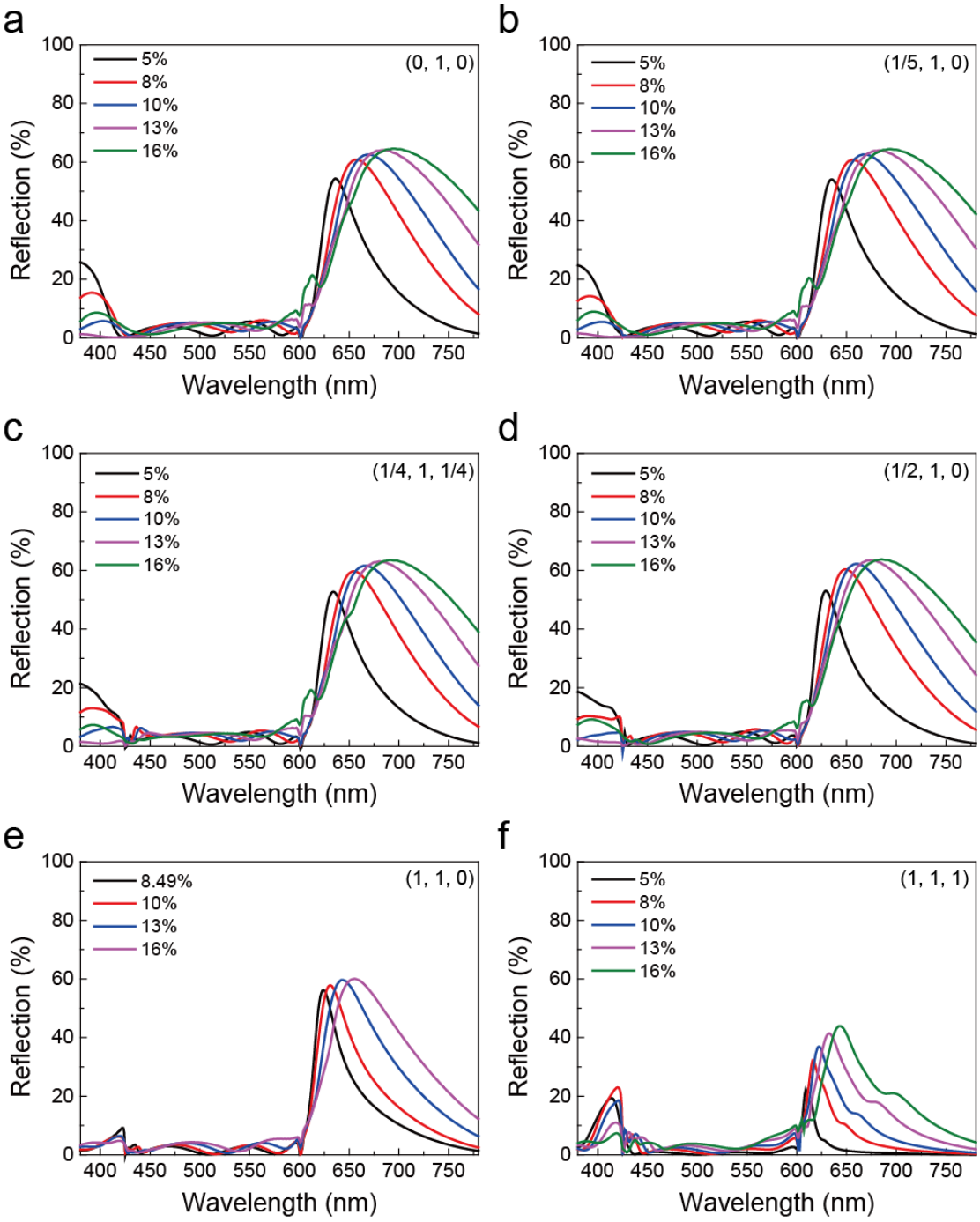

Fig. S7 Optical response under different VFs. Reflection spectra at states **a** (0, 1, 0), **b** (1/5, 1, 0), **c** (1/4, 1, 1/4), **d** (1/2, 1, 0), **e** (1, 1, 0), and **f** (1, 1, 1).

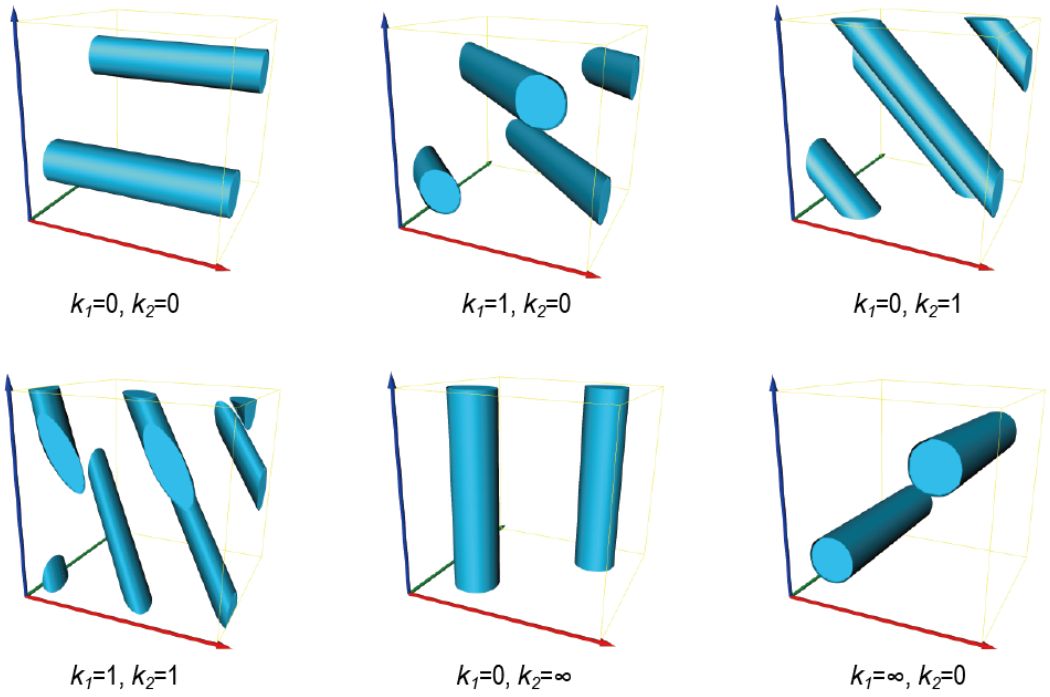

Fig. S8 Schematic diagram of tubular structures in omni direction.