Carbon Nanotubes Kirigami Mechanical Metamaterials

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(1) Poisson's ratios of all the CNT-k

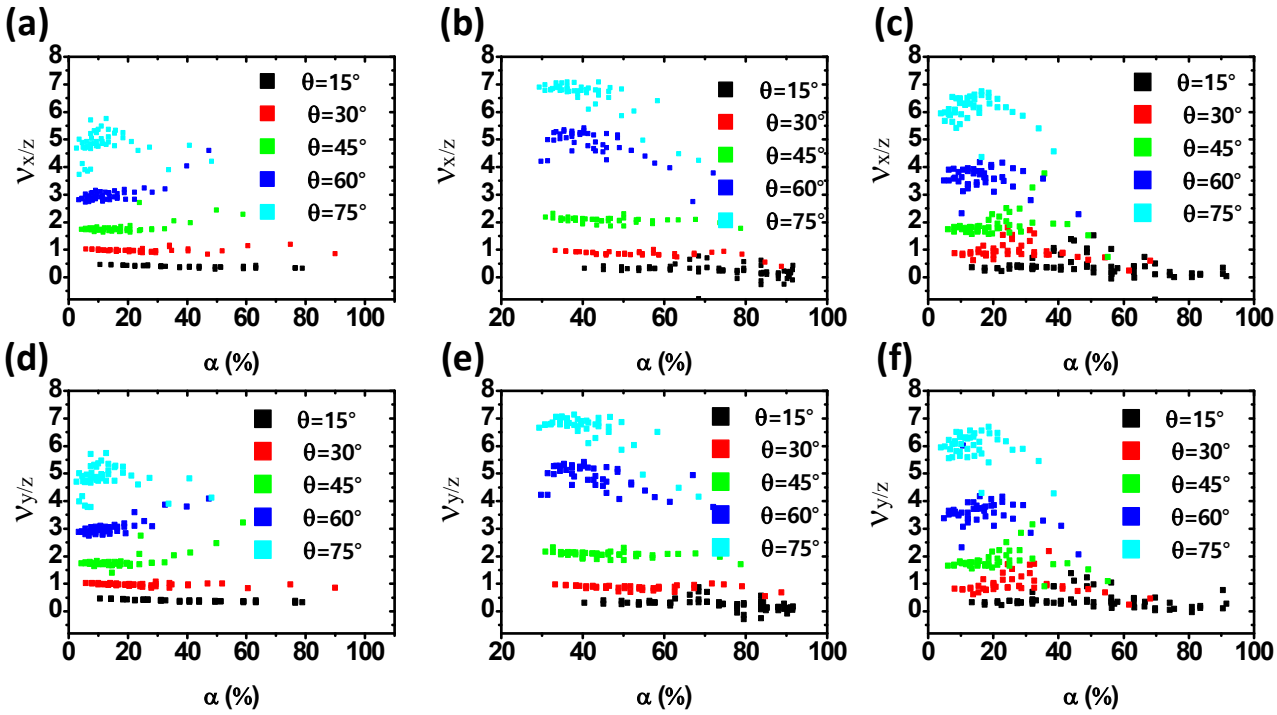

Figure S1 Influence of ratio of surface area of CNT-k to that of pristine CNT on Poisson's ratio (*xz* and *yz*) for the three types of CNT-k with θ ranging from 15°- 75°. (a) and (d) for OCK; (b) and (e) for RCK; (c) and (f) for ECK, respectively.

In the main text, a newly dimensionless geometry parameter α is defined to characterizes the

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mechanical properties of the CNT-k. In order to calculate α (the ratio of surface area of CNT-k to that of pristine CNT), unique unit cells for OCK, RCK and ECK are drawn as follow Figures S1-3.

(2) Geometrical Parameter α for OCK

According to the definition of α, a vacuum area in the dash orthogon is required to determined. It is noted that S_M and S_T are the area of kirigami (marked by blue) and orthogonal unit cell (dashed box).

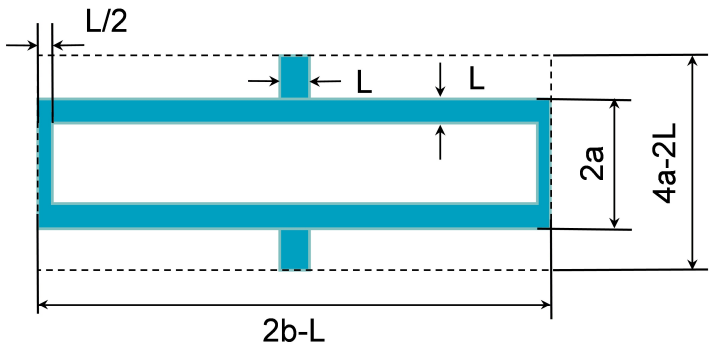

Figure S1 Schematic of one orthogonal unit cell where various structural parameters are indicated.

S_M and S_T are calculated as follow;

$$S_T = (2b - L)(4a - 2L) = 8ab - 4aL - 4bL + 2L^2 \tag{1}$$

$$S_M = 2a(2b - L) - (2a - 2L)(2b - 2L) + L(4a - 2L - 2a) = 4aL + 4bL - 6L^2 \tag{2}$$

The geometrical parameter α for OCK can be therefore obtained by

$$\alpha_{OCK} = \frac{S_M}{S_T} = \frac{4aL + 4bL - 6L^2}{8ab - 4aL - 4bL + 2L^2} = \frac{4bL(1+\tan\theta) - 6L^2}{8b^2\tan\theta - 4bL(1+\tan\theta) + 2L^2} \tag{3}$$

(3) Geometrical Parameter α for RCK

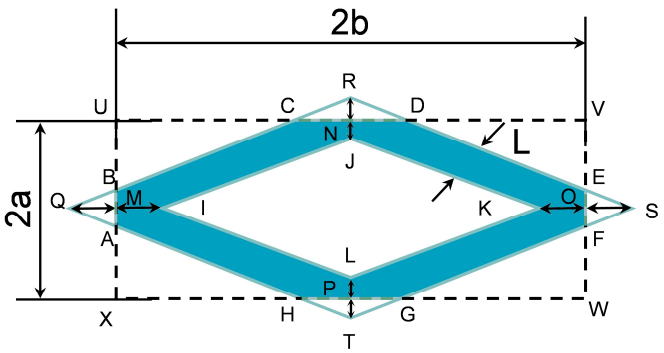

Figure S2 Schematic of one planar unit cell of RCK where various structural parameters are indicated.

Based on the symmetrical feature of the rhomboid, it can be determined that KO=OS=QM=MI, RN=NJ=LP=PT and $\tan\theta = \frac{b}{a}$.

where

$$IK = 2(b - \frac{L}{\sin\theta}) \tag{4}$$

$$VE = a - \frac{L}{2\cos\theta} \tag{5}$$

$$DV = b - \frac{L}{\sin\theta} \tag{6}$$

And

$$S_T = XW \bullet WV = 4ab \tag{7}$$

$$S_M = S_T - S_{IJKL} - 4S_{EVD} \tag{8}$$

$$S_{IJKL} = IK \bullet JL = IK^2 \bullet \tan\theta = (b - \frac{L}{\sin\theta})^2 \tan\theta \tag{9}$$

$$S_{EVD} = \frac{VE \bullet DV}{2} = \frac{(a - \frac{L}{2\cos\theta})(b - \frac{L}{\sin\theta})}{2} \tag{10}$$

Finally, the geometrical parameter α for RCK can be expressed by

$$\begin{aligned} \alpha_{RCK} &= \frac{S_M}{S_T} = \frac{4ab - 2(a - \frac{L}{2\cos\theta})(b - \frac{L}{\sin\theta}) + (b - \frac{L}{\sin\theta})^2 \tan\theta}{4ab} \\ &= \frac{4ab\cos\theta\sin\theta - 2aL\cos\theta - 2bL\sin\theta + L^2 + 2b^2\sin^2\theta - 4bL\sin\theta + 2L^2}{8ab\sin\theta\cos\theta} \end{aligned} \tag{11}$$

(4) Geometrical Parameter α for ECK

Based on the symmetrical feature and the schematic, it can be determined that KO=OS=QM=MI=RN=NJ=LP=PT=L/2.

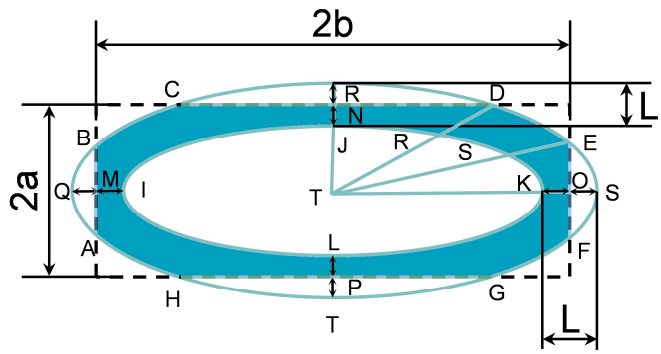

Figure S3 Schematic of one planar unit cell of ECK where various structural parameters are indicated.

And

$$ND = \frac{2b+L}{2(2a+L)}\sqrt{4aL+L^2} \tag{12}$$

$$OE = \frac{2a+L}{2(2b+L)}\sqrt{4bL+L^2} \tag{13}$$

$$\theta_{ETR} = \arccos\left(\frac{1}{2b+L}\sqrt{4bL+L^2}\right) \tag{14}$$

$$\theta_{DTR} = \arccos\left(\frac{2a}{2a+L}\right) \tag{15}$$

$$S_T = 4ab \tag{16}$$

$$S_M = 4\left(S_{NDT} + S_{DET} + S_{EOT} - S_{JKT}\right) \tag{17}$$

$$S_{NDT} = \frac{NT \bullet ND}{2} = \frac{a(2b+L)}{4(2a+L)}\sqrt{4aL+L^2} \tag{18}$$

$$S_{EOT} = \frac{OT \bullet OE}{2} = \frac{b(2a+L)}{4(2b+L)}\sqrt{4bL+L^2} \tag{19}$$

$$S_{DET} = \frac{TS \bullet TR}{2}(\theta_{ETR} - \theta_{DTR}) = \frac{(2a+L)(2b+L)}{8}\left(\arccos\left(\frac{1}{2b+L}\sqrt{4bL+L^2}\right) - \arccos\left(\frac{2a}{2a+L}\right)\right) \tag{20}$$

$$S_{JKT} = \frac{\pi \bullet TK \bullet TJ}{4} = \frac{\pi(2a-L)(2b-L)}{16} \tag{21}$$

Finally, the geometrical parameter α for ECK is calculated as

$$\alpha_{ECK} = \frac{S_M}{S_T} = \frac{\left(\frac{2ab+aL}{2a+L}\right)\sqrt{4aL+L^2} + \left(\frac{2ab+bL}{2b+L}\right)\sqrt{4bL+L^2} + \frac{(2a+L)(2b+L)}{2}\left(\arccos\left(\frac{1}{2b+L}\sqrt{4bL+L^2}\right) - \arccos\left(\frac{2a}{2a+L}\right)\right) - \frac{\pi(2a-L)(2b-L)}{4}}{4ab} \tag{22}$$