Supplementary Information (SI) for Soft Matter.

Supplementary Information

Surface Buckling Enabled Soft Clutch

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I. Theoretical mechanics model for tensile strength

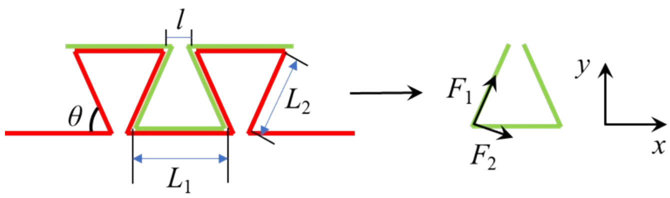

Figure S1. Force analysis of the inverted trapezoidal structure before buckling.

During tensile stretch of the 2D soft clutch, the long base of the trapezoid were laterally squeezed and the legs of the trapezoid were under tension (Figure S1). After that, the compressed long base lost stability and buckled. Focusing on one trapezoid and ignoring the friction between film legs, we have the following force analysis.

Force balance in y-direction:

$$F_1\sin\theta=F_2\cos\theta \tag{S1}$$

where F_1 is the tensile force acting on film legs, and F_2 represents the force acting on the long base of the trapezoid from adjacent film leg.

The critical stress for buckling in the x-direction (F_{cr}) can be written as:

$$F_{cr}=F_2\sin\theta+F_1\cos\theta=\pi^2 EI/(\mu L_1)^2 \tag{S2}$$

where E is the elastic modulus of the film, $I=w_f t_f^3/12$ is the moment of inertia of the film, and μ

is the equivalent length coefficient sensitive to boundary conditions and material imperfections.

The normal force acting on half clutch in the y-direction is,

$$F_N=2NF_1/\sin\theta \tag{S3}$$

The tensile strength of the clutch is,

$$\sigma_{max}=F_N/[N(L_1+l)w_f] \tag{S4}$$

where $l=L_1-2L_2\cos\theta$ is the short base of the trapezoid, and $N(L_1+l)$ is the total length of the half clutch.

Based on above equations, we obtain,

$$\sigma_{max}=\pi^2EI/[\mu^2w_fL_1^2\tan\theta(L_1-L_2\cos\theta)] \tag{S5}$$

II. Theoretical mechanics model for detachment strength

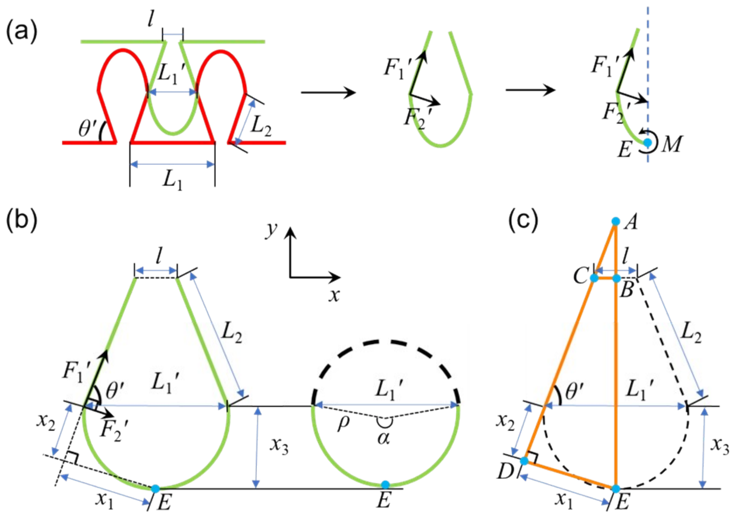

Figure S2. **(a)** Force analysis of the trapezoidal structure at the critical disengagement point, **(b)** geometry of the deformed trapezoid, and **(c)** △ABC∽△ADE.

For the clutch in the critical disengagement state, an inverted trapezoidal film structure is selected as the research object for force analysis as follows.

According to Figure S2(a), a geometric equation can be written as,

$$L_1=L_1'+2L_2\cos\theta' \tag{S6}$$

$$l=L_1'-2L_2\cos\theta' \tag{S7}$$

where L_1' is the lateral length of the long base of the trapezoid after bending deformation, θ' is the angle between film leg and the substrate after bending deformation. According to Eq. (S6) and (7), it can be determined that $L_1'=L_1-L_2\cos\theta$ and $\theta'=\arccos(0.5\cos\theta)$.

From Figure S2(c), regarding the deformed long base (L_1) as a segment of arc, we have,

$$L_1=\rho\alpha \tag{S8}$$

$$L_1'= L_1-L_2\cos\theta=2\rho\sin(\alpha/2) \tag{S9}$$

where ρ and α (rad) are the curvature radius and radian of the long base of the trapezoid after bending deformation. Based on Eq. (S8) and (S9), ρ and α can be solved.

According to the geometric relationship that △ABC∽△ADE in Figure S2 (d), we have，

$$x_1/(0.5l)=(x_2+L_2+0.5l/\cos\theta')/(0.5l\tan\theta')=(0.5l\tan\theta'+L_2\sin\theta'+x_3)/(0.5l/\cos\theta') \tag{S10}$$

We can derive x_3 from the geometric relationship shown in Figure S2(b) and (c),

$$x_3=\rho+\rho\cos[(2\pi-\alpha)/2] \tag{S11}$$

Based on Eq. (S10) and (S11), x_1, x_2, and x_3 can be obtained.

Physical equation:

$$1/\rho=M/(EI) \tag{S12}$$

Force balance in y-direction:

$$F_1'\sin\theta'=F_2'\cos\theta' \tag{S13}$$

Moment balance equation with reference to point E:

$$F_1'x_1+F_2'x_2-M=0 \tag{S14}$$

Among them, M is the bending moment at bottom point (point E), F_1' is the tensile force of the film leg, F_2' is the force from adjacent film leg, x_1 and x_2 are the lever arms of F_1' and F_2' with respect to point E, respectively, x_3 is the height of the arc.

Substituting Eq. (S12) and (S13) into Eq. (S14), F_1' can be calculated.

The normal force acting on half clutch in the y-direction is,

$$F_N'=2NF_1'/\sin\theta' \tag{S15}$$

and the detachment strength of the clutch is,

$$\sigma_{det}=F_N'/[N(L_1+l)w_f] \tag{S16}$$

Ultimately, we obtain,

$$\sigma_{det}=EI\cos\theta/[2\rho^2 \sin\theta' \, w_f \, (1-\cos(\alpha/2) \, (L_1-L_2\cos\theta)] \tag{S17}$$