Electronic Supplementary Material (ESI) for Soft Matter

Supplementary Information 1 (S1)

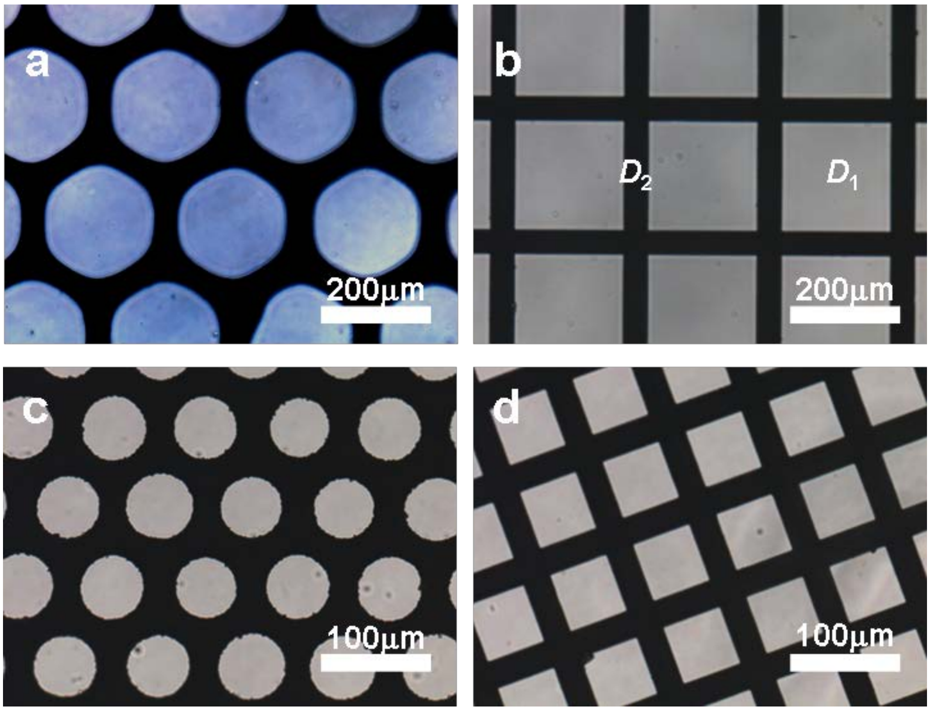

Fig. S1 Optical images of the applied copper grid: (a) H100; (b) S100; (c) H300; (d) S300.

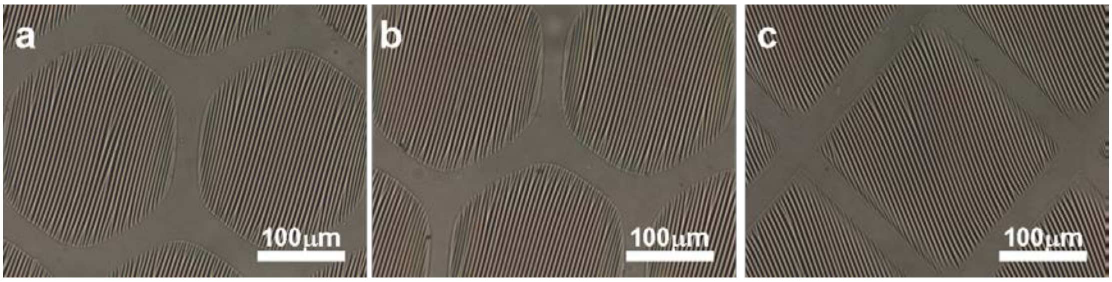

Fig. S2 Optical images of the patterned PDMS wrinkles from the first OPT for 15 min (a), followed by the second OPT for 15 min (b,c). The applied copper grid: (a,b) H100; (c) S100.

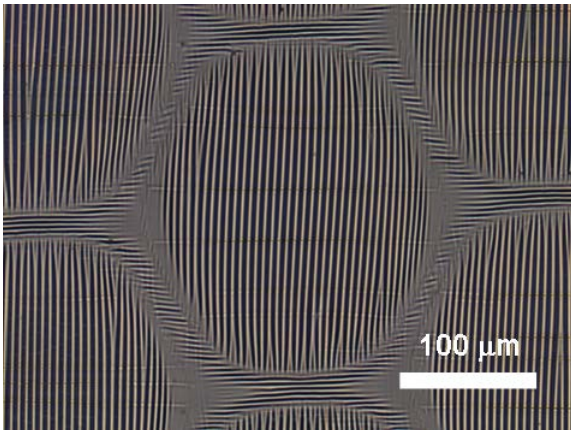

Fig. S3 Optical image of the patterned PDMS wrinkles in the case of $t_1 = 20$ min and $t_2 = 10$ min followed by the post-treatment.

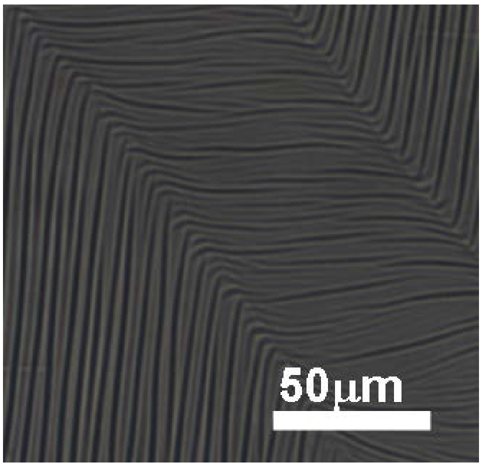

Fig. S4 Optical image of the patterned (Pt/SiOx)/PDMS wrinkles in the case of $t_1 = t_2 = 10$ min and the ion-sputtered 4 nm-thick Pt film.

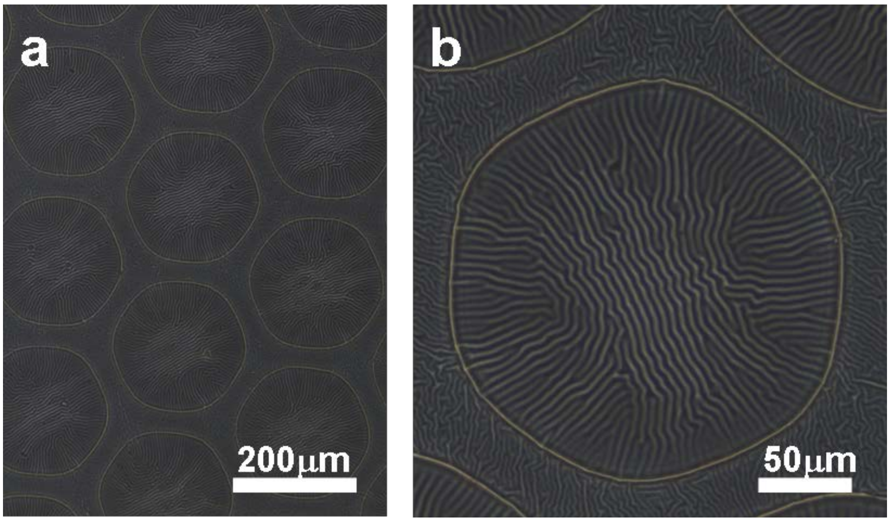

Fig. S5 Optical images of the patterned (Pt/SiOx)/PDMS wrinkles in the case of $t_1 = t_2$ = 10 min and the ion-sputtered 8 nm-thick Pt film. It is noted that the two times' OPT were both carried out on the strain-free PDMS sheet.

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Supplementary Information 2 (S2)

Our analysis below closely follows those given by Koiter for Winkler's foundation,[46] but here the foundation stiffness is different; instead of Wrinkler foundation we use the foundation stiffness by Biot [47] which depends on the wrinkling wavelength and is obtained by assuming the substrate as an elastic half-space.

Assuming the deflection in the following form

$$w(X) = a \sin kX \tag{S-1}$$

Inserting Eq. (S-1) into (1.2) gives

$$P_2[w;N] = \frac{1}{4}\left[Bk^4 + c - Nk^2\right]a^2 \tag{S-2}$$

When the axial force N is small, $P_2>0$ and the system is stable. At the critical buckling state, $P_2 = 0$ and in this case from Eq. (S-2), we have

$$N_1 = k^2 B + \frac{c}{k^2} = k^2 B + \frac{1}{2k}\bar{E}_s \tag{S-3}$$

The minimum critical load corresponding to

$$k = \left(\frac{\bar{E}_s}{4B}\right)^{\frac{1}{3}} \tag{S-4}$$

is given by

$$N_{\min} = \frac{3}{4}\left(4\bar{E}_s^{\,2}B\right)^{\frac{1}{3}} \tag{S-5}$$

From Eqs. (1.4), (S-1) and (S-5), we obtain

$$P_4[w;N_{\min}] = -\frac{5}{1024}\frac{\bar{E}_s^{\,2}}{B}a^4 \tag{S-6}$$

Eq. (S-6) indicates that $P_4 < 0$ and the buckled film is very soft.

To further illustrate this point, we explore below the tangent stiffness of the system beyond the bifurcation point. When N is beyond $N_{\min}$, increment of the second variation P_2 reads

$$\begin{aligned}\Delta P_2\left[w;N_{\min}\right] &= \frac{k}{2\pi}\int_0^{2\pi/k}\left[-\frac{1}{2}\left(N-N_{\min}\right)a^2k^2\cos^2 kX\right]\mathrm{d}X \\ &= \frac{1}{4}(1-\lambda)a^2N_{\min}k^2\end{aligned} \tag{S-7}$$

where $\lambda = N/N_{\min}$. From Eqs. (S-4), (S-5) and (S-7) we have

$$\Delta P_2\left[w;N_{\min}\right] = \frac{3}{16}(1-\lambda)a^2\bar{E}_s\left(\frac{\bar{E}_s}{4B}\right)^{1/3} \tag{S-8}$$

Based on Eqs. (S-6) and (S-8), we have the function F defined in the general theory of Koiter in the following form

$$F(a;\lambda) = \frac{3}{16}(1-\lambda)a^2\bar{E}_s\left(\frac{\bar{E}_s}{4B}\right)^{1/3} - \frac{5}{1024}\frac{\bar{E}_s^{\,2}}{B}a^4 \tag{S-9}$$

The equilibrium condition reads

$$\frac{\partial F}{\partial a} = \bar{E}_s\left(\frac{3}{8}(1-\lambda)\left(\frac{\bar{E}_s}{4B}\right)^{1/3}a - \frac{5}{256}\frac{\bar{E}_s}{B}a^3\right) = 0 \tag{S-10}$$

Eq. (S-10) gives

$$a^2 = \frac{24}{5}(1-\lambda)\left(\frac{\bar{E}_s}{4B}\right)^{-2/3} \tag{S-11}$$

The shorting after the onset of buckling is given by

$$\begin{aligned}-\Delta l &= \int_0^{2\pi/k}\left[\sqrt{1-w'^2}-1\right]\mathrm{d}X \approx \int_0^{2\pi/k}\frac{1}{2}w'^2\,\mathrm{d}X \\ &= \frac{6}{5}(1-\lambda)\frac{2\pi}{k}\end{aligned} \tag{S-12}$$

Further we obtain

$$\frac{1}{E_t h} = \frac{\partial\left(-\Delta l/\left(2\pi/k\right)\right)}{\partial N} = -\frac{6}{5N_{\min}} \tag{S-13}$$

Eq. (S-13) gives the tangent stiffness of the buckled film as

$$E_t = -\frac{5}{6}\frac{N_{\min}}{h} \tag{S-14}$$

which is negative, indicating that the buckled film is much softer than its ground state, which is consistent with the conclusion drawn from Eq. (S-6).