Supplementary information

Guided fracture of films on soft substrates to create micro/nano-feature arrays with controlled periodicity

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Discussion on fracture on gold film.

It should be emphasized that the fracture for both the oxidized film and the gold film were brittle in nature. All nano-scale thin metal films (including metals) are inherently brittle (in the rigorous sense of the word used to describe the energy dissipated per unit area of crack advance), with a toughness that can be estimated approximately by the product of the thickness and yield strength as being less than about 50 J/m^2 for a 100 nm film. However, when the film is supported on a relatively stiff substrate, the energy-release rate for crack channeling is limited by the fracture mechanics, and the applied strain for crack channeling is about 5%[1,2], which tends to be higher than the yield strain. Conversely, if the film is supported on a very compliant substrate, the energy-release rate is much higher[2,3], and the strain required for crack channeling is lower, resulting in the observed brittle behavior on substrates such as PDMS. Furthermore, in the absence of a constraint, such as when the film is unsupported[4] or supported on a very complaint material such as PDMS [5] fracture is initiated by shear localization at the onset of yield. The film deforms in an elastic fashion up to relatively high strains because of an elevated yield stress, and then catastrophically ruptures because of the shear localization. Only when a thin metal film is supported on a substrate with a reasonable modulus, capable of providing significant constraint to the deformation and reducing the magnitude of the energy-release rate for channel cracking, can ductile behavior be induced[6].

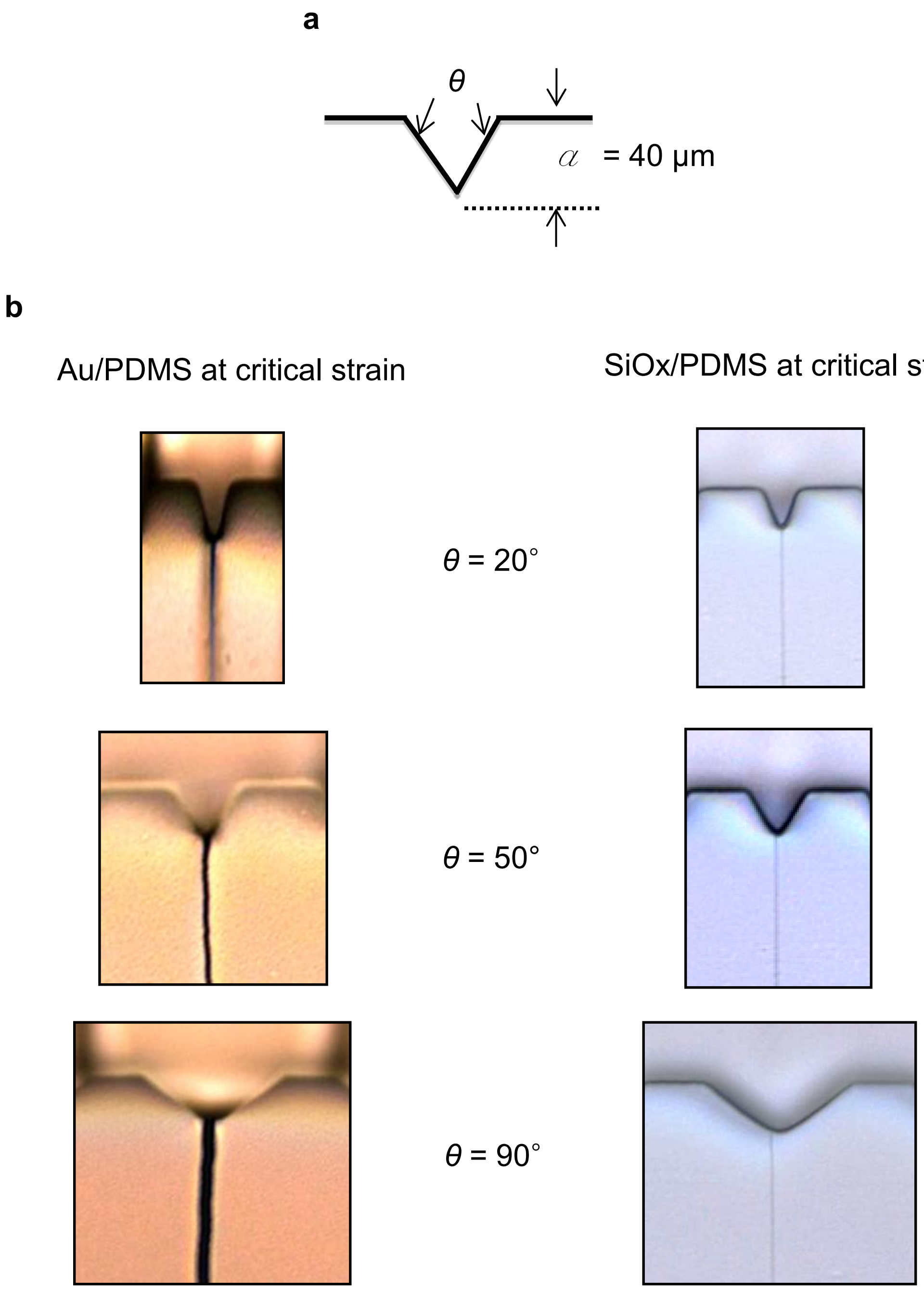
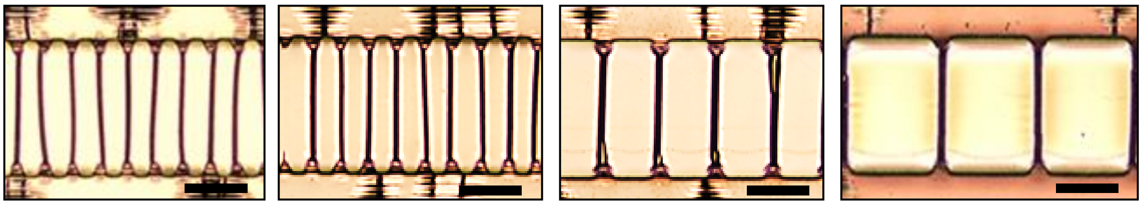


Figure 1S| Cracking relatively independent of 'V-notch' angle. a, Schematics of multilayer structures with V-notches having different angles, θ. **b,** Crack formation in Au/PDMS and SiOx/PDMS bilayer systems under applied uniaxial tensile force. θ = 20°, 50°, 90° with a notch of fixed length a = 40 μm. but different anges.

a



b

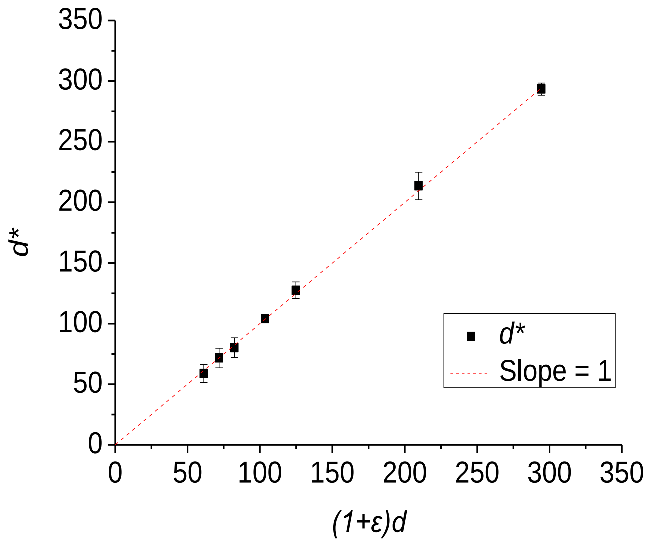


Figure 2S | Periodic uniformity of cracking on Au/PDMS layer. a, Controlled spacing of the cracks on Au surface with different spacing between notches, d, (47.7 μm < d < 277.7 μm), Scale bar: 200 μm. **b,** Comparison of measured dimensionless crack spacing (d^*) and dimensionless spacing considering the applied strain,$(1+\varepsilon)d$ on Au/PDMS system at ε ~ 10%. The slope of the dash line ~ 1.

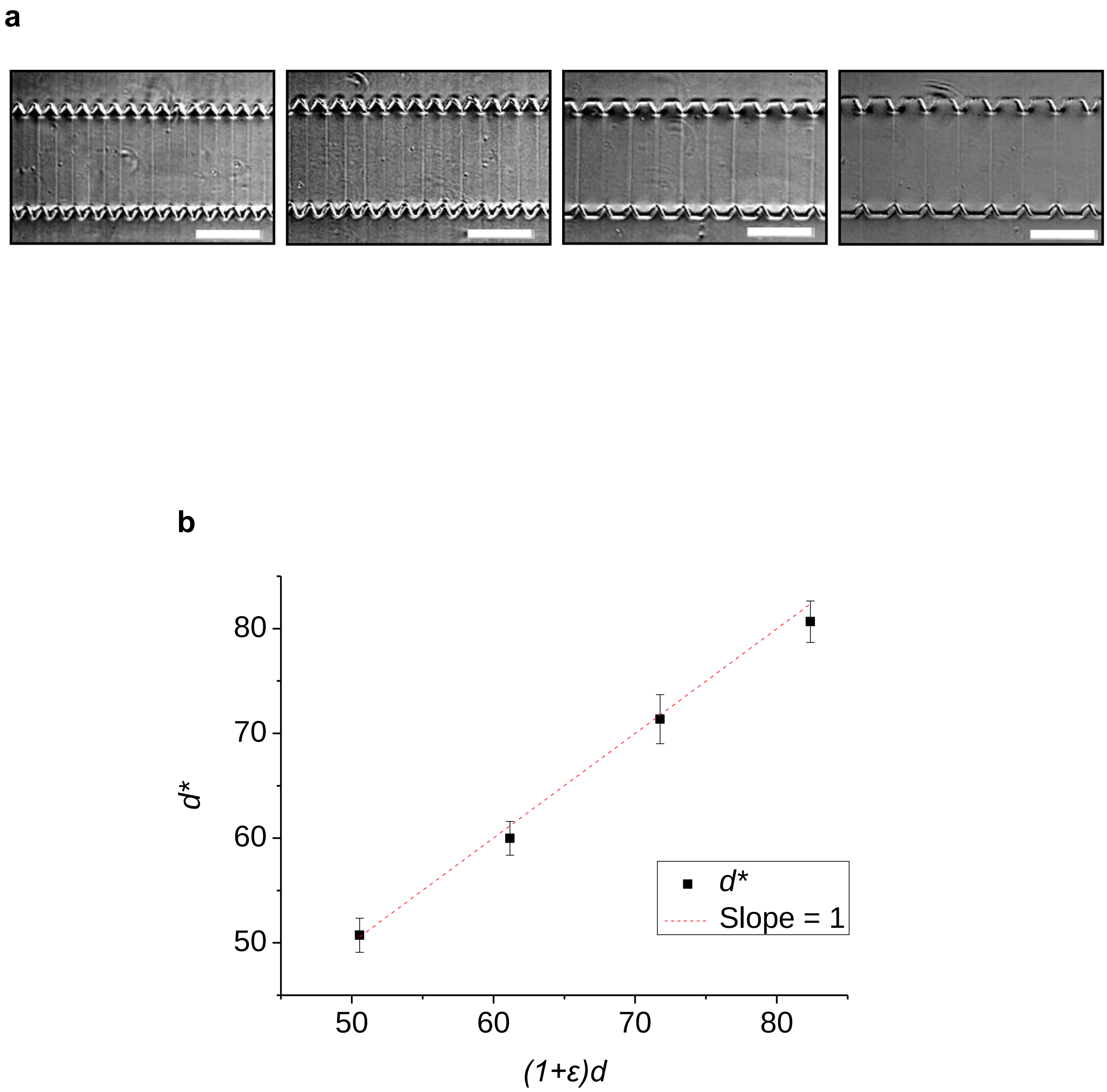


Figure 3S | Periodic uniformity of cracking on SiO_x/PDMS bilayer. a, Controlled spacing of the cracks formed on oxidized PDMS surface as spacing between notches, d, was changed (47.7 μm < d < 117.7 μm), Scale bar: 200 μm. **b,** Comparison of measured dimensionless crack spacing (d^*) and dimensionless spacing considering the applied strain,$(1+\varepsilon)d$ on SiO_x/PDMS system at ε ~ 6%. The slope of the dash line ~ 1.

Discussion on periodic uniformity of cracking.

The cracks on Au/ PDMS layers were successfully formed in a uniform periodic manner depending on d, (47.7 μm < d < 277.7 μm) (Fig. 1a). At high strains, wrinkles were found in mostly micro-groove area and uniform cracking area. However, it did not affect the uniformity of cracking. Similarly, periodic uniform cracking on the SiO_x/PDMS bilayer were induced with the controlled spacing, d (47.7 μm < d < 117.7 μm) (Fig. 2a). The measured dimensionless spacing, d^*, in both structures closely matched the designed dimensionless spacing ,(1+ε)d (Fig 1b and 2b).

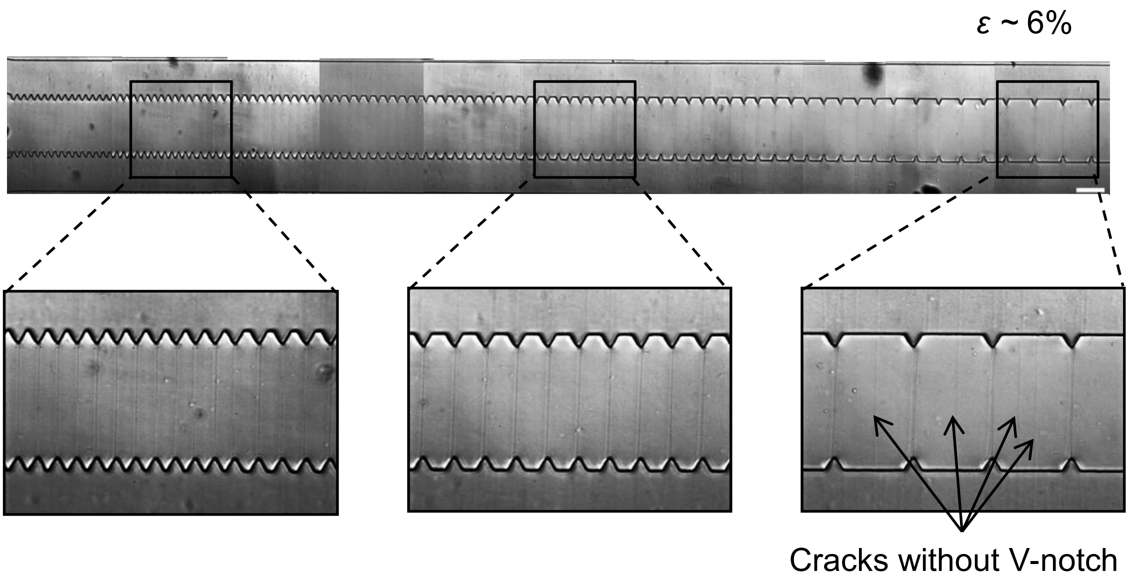


Figure 4S | Crack formation on SiO_x/PDMS systems that have different spacings between V-notches. At a given strain condition, short spacing regions have uniformly periodic cracks, whereas cracks are formed at V-notches as well as randomly in regions between notches where the spacing between notches is larger. Scale bar: 200 μm.

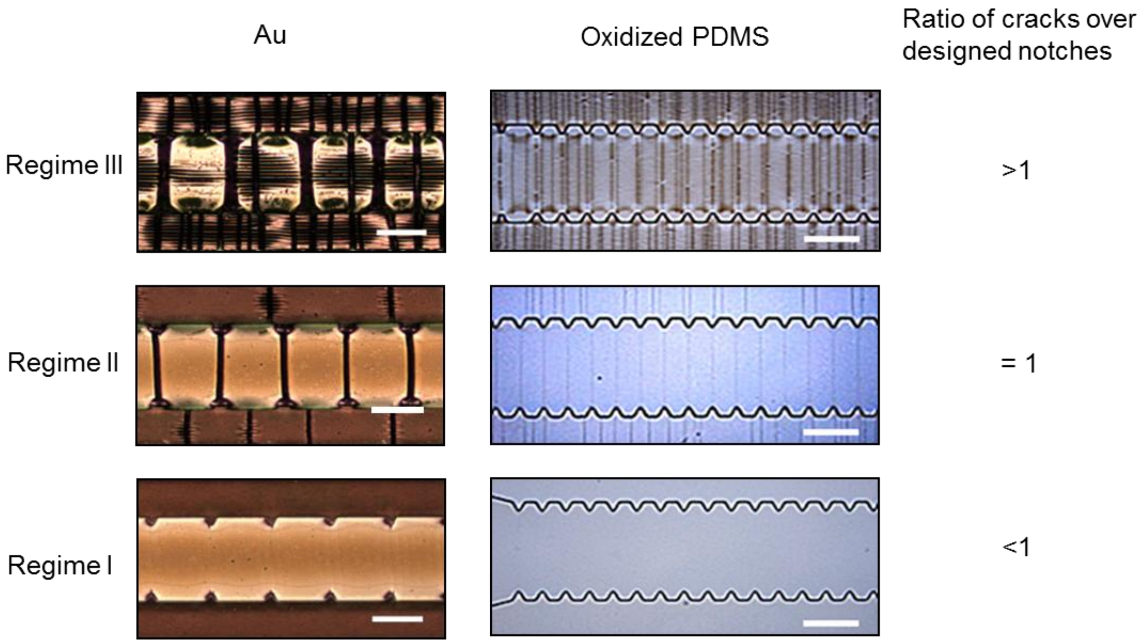


Figure 5S | Representative images of Au/PDMS layers and SiOx/PDMS layers under different cracking regimes are provided. Scale bar: 200 μm.

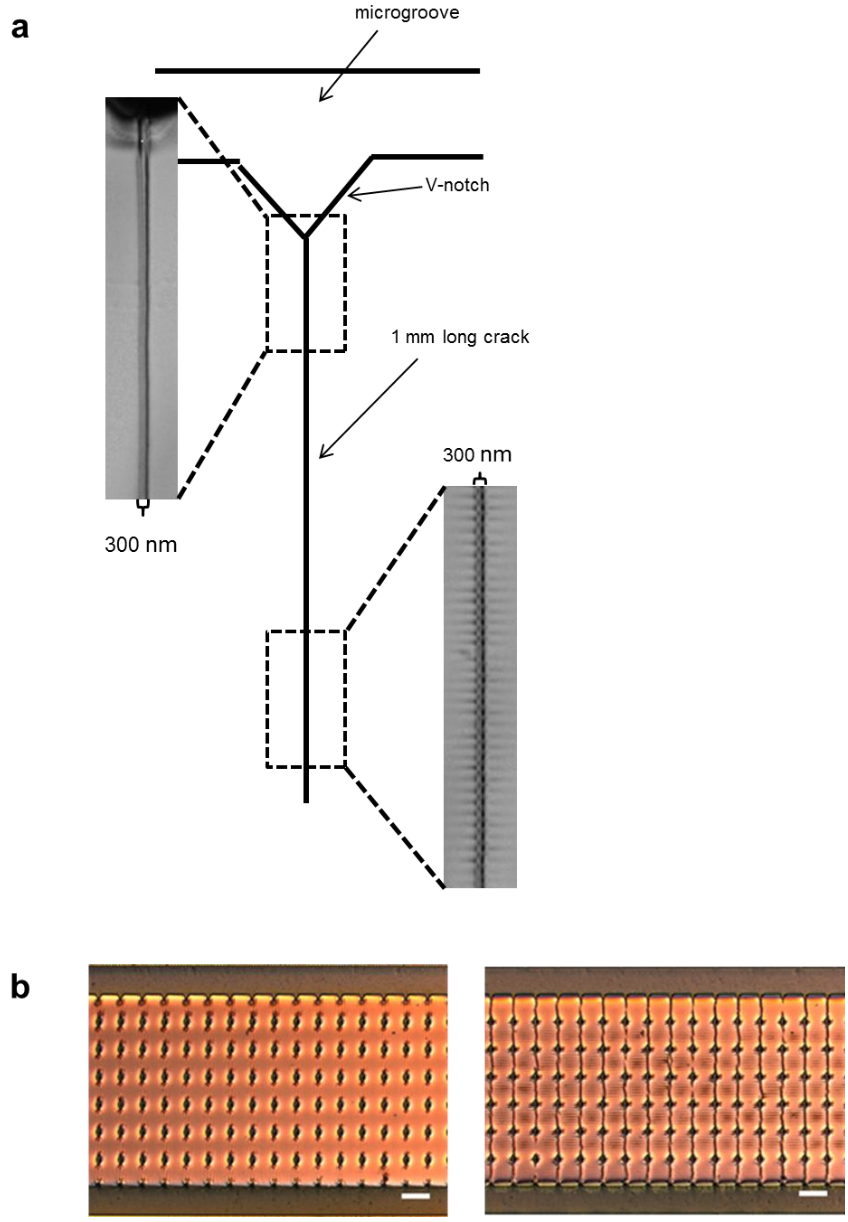


Figure 6S | Millimeter long crack. a, millimeter long and nano-sized crack in SiOx/PDMS system. **b,** arrays of millimeter long, micron sized cracks in Au/PDMS system with the help of ordered diamond notches.

a

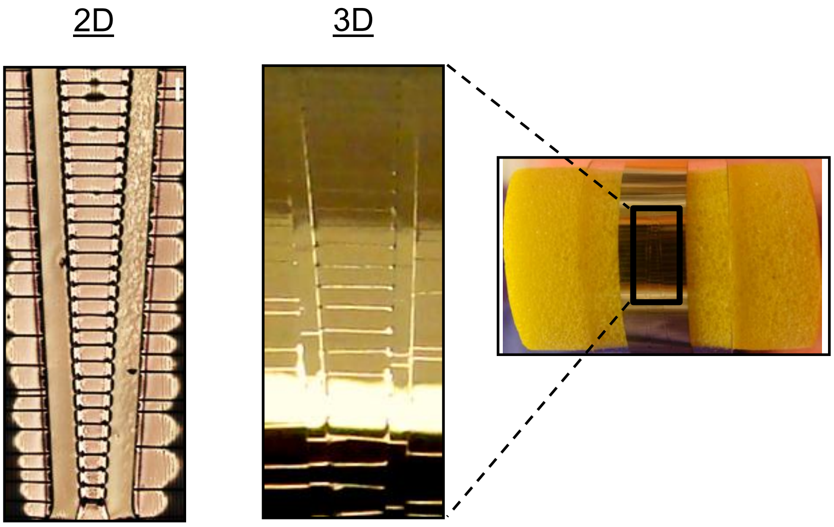


Figure 7S | Uniformly spaced cracks patterns of different lengths formed on curved surface. a, Demonstration of increasing crack lengths produced in a rolled Au/PDMS sheet on a foam cylinder. Cracks are formed from notches both on flat (*left*) and curved (*right*) substrate.

Design spacing (μm)	Control	57.70	67.70	77.70	97.70	117.70	197.70	277.70
Spacing at ε ~ 10% (μm)	-	63.47	74.47	85.47	107.47	129.47	217.47	305.47
Average (μm)	335.52	59.98	71.63	80.17	103.99	127.46	213.55	293.41
S.D	179.45	1.62	8.12	8.08	2.54	6.81	11.38	5.04

Table 1S | Statistical results of crack spacing on Au/ PDMS layer.

Design spacing (μm)	Control	47.70	57.70	67.70	77.70
Spacing at ε~ 6% (μm)	-	50.56	61.16	71.76	82.36
Measured spacing (μm)	27.43	50.72	59.98	71.35	80.66
Standard deviation (SD)	16.97	1.63	1.62	2.35	1.97

Table 2S | Statistical results of crack spacing on SiO_x/PDMS bilayer.

Supplementary Movie | Crack generation

References

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