Supporting Information: Photothermally-Reprogrammable Buckling of Nanocomposite Gel Sheets

Adam W. Hauser[a], Arthur A. Evans[b], Jun-Hee Na[a] and Ryan C. Hayward*[a]

[a] A. W. Hauser, J.-H. Na, R. C. Hayward
Department of Polymer Science & Engineering
University of Massachusetts, Amherst, MA 01003, USA
E-mail: hayward@umass.edu

[b] A. A. Evans
Department of Physics
University of Massachusetts, Amherst, MA 01003, USA

Supporting figures:

Figure S1. Representative UV-Vis spectrum of an aqueous solution of NIPAM containing 0.1 wt. % gold nanoparticles (left). The extinction coefficient determined for the surface plasmon resonance maximum (at 510 nm) is used to determine the transmittance through the gel as a function of thickness for different nanoparticle loadings, as shown for the examples of 0.5 wt% and 1 wt% Au (right). The transmittance through the thickness is held at 0.70 (Absorbance of 0.15) for all sheets studied in the main text.

Figure S2. Temperature contour plot calculated from equation 5 below; the boxed area corresponds to the size of the heat source, i.e., the illuminated region.
**Heat conduction calculations:**

Ignoring the effects of convection, we can find the steady state solution for any distribution of injected heat by finding Green's function for Poisson's equation in three dimensions. For an arbitrarily distributed source, the temperature and solution are governed by

$$\nabla^2 T = \frac{-q(r)}{k}$$

$$T(r) = \frac{1}{k} \int d^3r' \frac{q(r')}{4\pi|\mathbf{r} - \mathbf{r}'|}$$

where $\mathbf{r}$ is the position in space, $\mathbf{r}'$ is the location of a differential heat source, $k$ is thermal conductivity, and $T$ is temperature. Considering a plate of linear dimensions $\ell, w, h$ with a uniform heat input per unit volume of $q$, eq. 2 becomes

$$T(x, y, z) = \frac{q}{2k} \int_{-\ell/2}^{\ell/2} dx' \int_{-w/2}^{w/2} dy' \int_{-h/2}^{h/2} dz' \frac{1}{\sqrt{(x-x')^2 + (y-y')^2 + (z-z')^2}}$$

(3)

For thin plates evaluated at $z = 0$, the integral simplifies to

$$T(x, y, 0) \approx \frac{qh}{2k} \int_{-w/2}^{w/2} dy' \int_{-\ell/2}^{\ell/2} dx' \frac{1}{\sqrt{(x-x')^2 + (y-y')^2}}$$

(4)

and the solution is

$$\frac{2kT(x, y, 0)}{qh} \approx -(w - 2y) \log \left( -\ell + 2x + \sqrt{(\ell - 2x)^2 + (w - 2y)^2} \right) +$$

$$+ (w - 2y) \log \left( \ell + 2x + \sqrt{(\ell + 2x)^2 + (w - 2y)^2} \right) -$$

$$+ (\ell - 2x) \log \left( 2y - w + \sqrt{(\ell - 2x)^2 + (w - 2y)^2} \right) -$$

$$+ (\ell + 2x) \log \left( 2y - w + \sqrt{(\ell + 2x)^2 + (w - 2y)^2} \right) +$$

$$+ (\ell - 2x) \log \left( 2y + w + \sqrt{(\ell - 2x)^2 + (w + 2y)^2} \right) -$$

$$+ (w + 2y) \log \left( 2x - \ell + \sqrt{(\ell - 2x)^2 + (w + 2y)^2} \right) +$$

$$+ (w + 2y) \log \left( 2x + \ell + \sqrt{(\ell + 2x)^2 + (w + 2y)^2} \right) +$$

$$+ (\ell + 2x) \log \left( 2y + w + \sqrt{(\ell + 2x)^2 + (w + 2y)^2} \right)$$

(5)

**Supporting videos:**

**SV1.** Selected shape transformations of a 25-µm-thick sheet, shown at 5x real time. The lateral size of the gel is 2.6 mm.

**SV2.** Selected shape transformations of a 25-µm-thick sheet with lower crosslinker content (1/2 of that described in experimental section) that shows more pronounced shape changes, shown at 5x real time. The lateral size of the gel is 2.8 x 1.7 mm.

**SV3.** A 1 x 2.5 mm strip of light is swept across 50-µm-thick gel sheets. Motion in the direction of the sweep is observed in all cases. Movie speed is 5x real time.