Supporting Information

10 μm thick ultra-thin glass sheet to realize a highly sensitive cantilever for precise cell stiffness measurement

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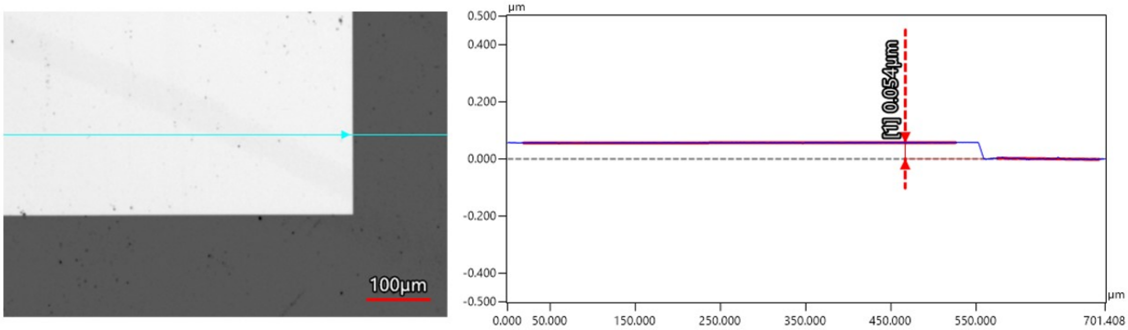

Fig. S1. Thickness measurement of foil pattern layers by a laser microscope.

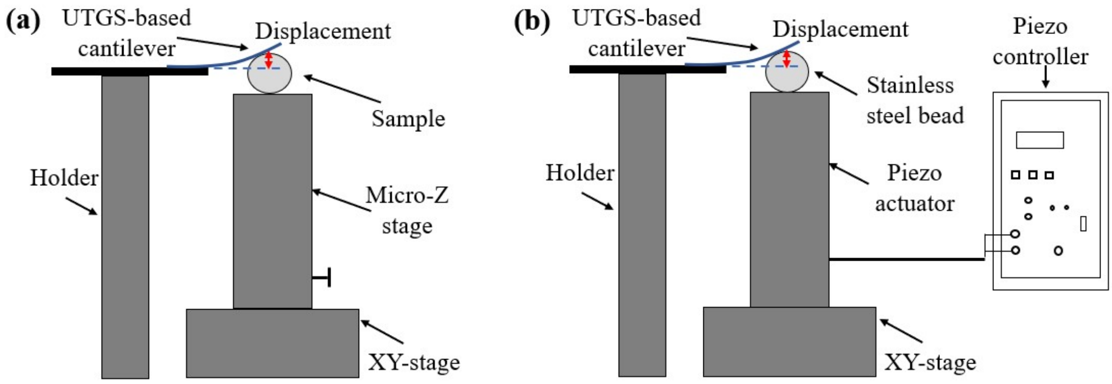

Fig. S2. Schematic illustration of the system setup: (a) Schematic view of the system setup for sample stiffness measurement (displacment: 5-25 μm). (b) Schematic view of the experimental setup for nanoscale displacment measurement (displacment: 0.5-1.0 μm).

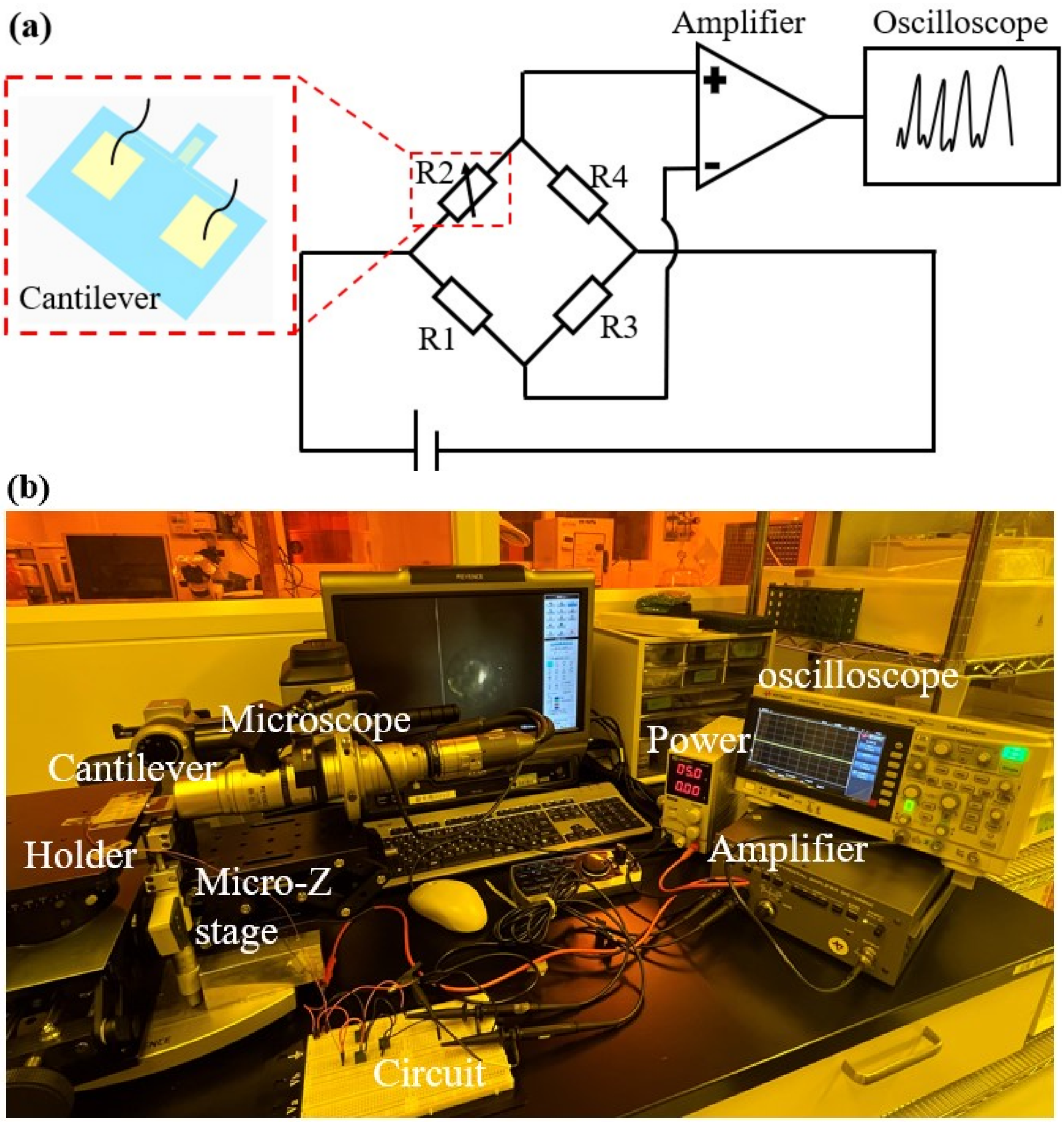

Fig. S3. Experimental measurement system: (a) Schematic image of the principle of measuring displacement of the UTGS-based cantilever using Wheatstone bridge circuit. (b) Experimental set-up.

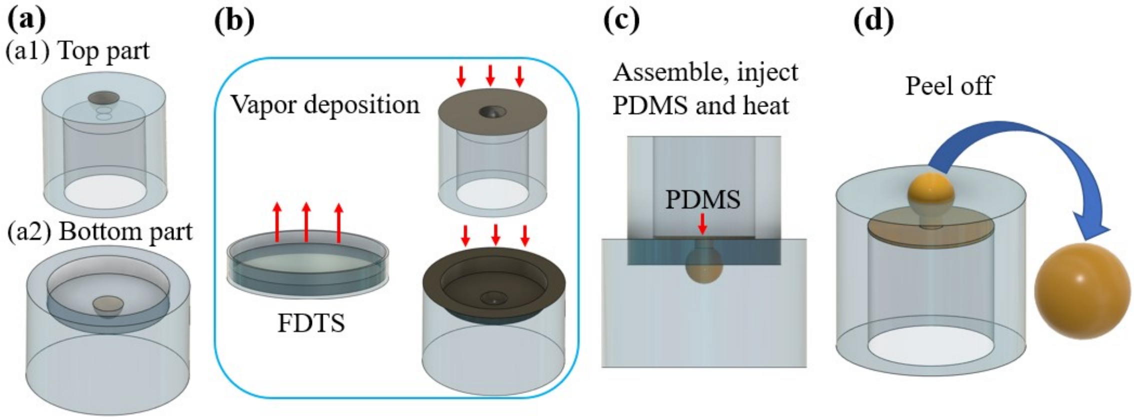

Fig. S4. Schematic illsutration of the preparation of the PDMS bead samples: (a) Print the two hemispherical molds by 3D printer: (a1) top part with a chamber and a hole for PDMS injection; (a2) bottom part. (b) Treat the surface of the molds by FDTS deposition. (c) Assemble the two hemispherical molds, inject PDMS and put them into an oven for curing. (d) Peel off the cured PDMS bead from the mold.

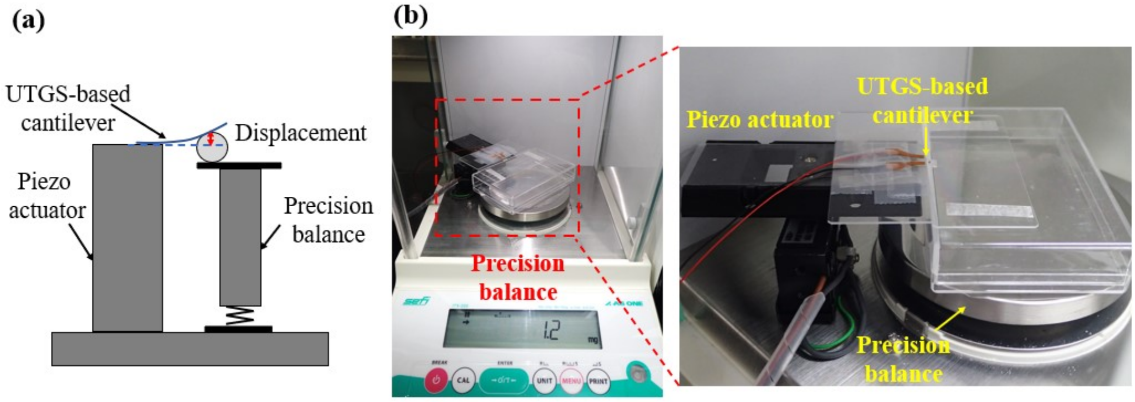

Fig. S5. System setup for measuring the force sensitivity of the fabricated UTGS-based cantilever: (a) Schematic illustration of the system setup. (b) A photograph of the setup for cantilever force calibration. A UTGS-based cantilever was mounted onto a piezo actuator that was used to move the cantilever to contact a precision balance. The precision balance was used for measuring forces applied to the free end of the cantilever beam.

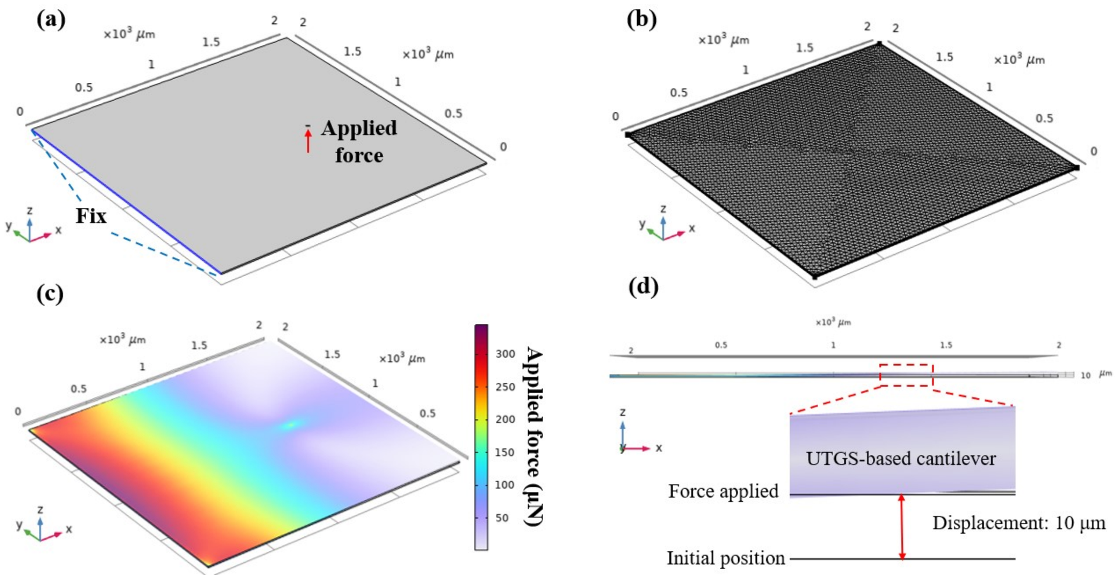

Fig. S6. Simulation performed by COMSOL: (a) Geometry and boundary conditions for simulation. The length, width and thickness of the model are 2 mm, 2 mm and 10 μm respectively. The position of the applied force is X: 1.4 mm, Y: 1.0 mm. (b) Mesh the 3D Model. (c) Simulation result of the applied force when the displacement is 10 μm. (d) Side view of the Model displacement indicating the displacement is 10 μm.

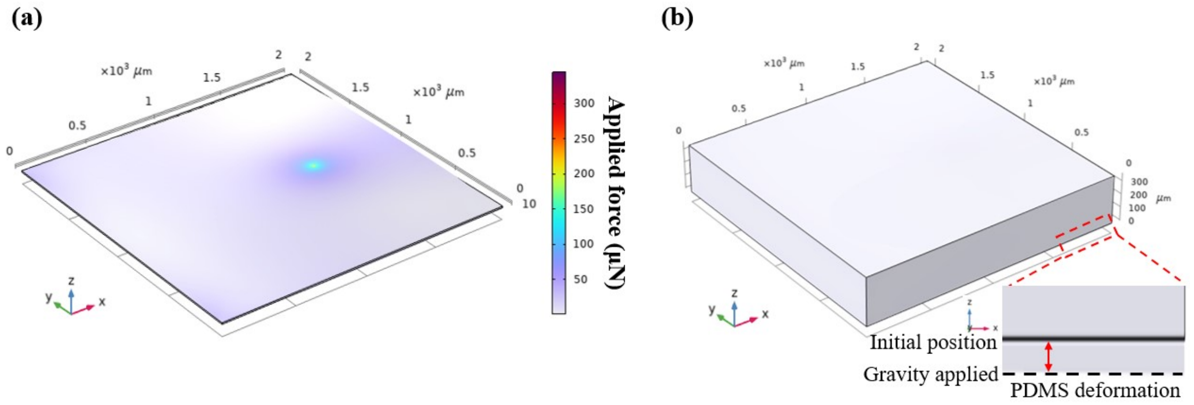

Fig. S7. Simulation results of the UTGS-based cantilever and PDMS performed by COMSOL: (a) UTGS model. (b) PDMS model.

Fabrication process of the UTGS

The key to the UTGS fabrication method is employing a weight-controlled load (WCL) to control the stretching length of the original commercial thick glass plate under a temperature condition below the softening point (full melting is not required) [1]. Four main components are necessary (Fig. 1(d)): an original commercial thick glass plate for stretching, a substrate glass plate (top) to hold it, and another substrate glass plate (bottom) with a WCL, and a high-temperature-resistant self-made carbon jig. The original commercial thick glass plate for stretching is 5 × 30 mm and 30 μm thick; the substrate glass plate (top) is 35 × 30 mm and 700 μm thick; and the substrate glass plate (bottom) is 20 × 30 mm and 700 μm thick. The overall fabrication process for fabricating UTGS can be summarized as follows. First, two holes (D = 6 mm) were made on the top substrate glass plate by using a hydrogen fluoride solution (46%, 35 min). Then the WCL (stainless steel nuts of different weights) was adhered on the bottom substrate glass plate using a high-temperature resistant adhesive. These two substrate glass plates were separately adhered to the top and bottom edges of the original commercial thick glass plate using the same high-temperature resistant adhesive. Next, it was fixed on the carbon jig and was put into the furnace (KDF-900GL; Denken, Kyoto) for thermal stretching. After heating and stretching, the UTGS structure was formed. Finally, a suitably slow cooling process was used to obtain the permanent UTGS. The changes of the original commercial thick glass plate dimensions by stretching are indicated in the upper middle part of Fig. 1(d).

Young's modulus calculation and measurement by Hertzian model

In this research, we treat the sample as a whole, the Young's modulus calculation reflects the mechanicals properties of the whole sample, which fits for the analysis by Hertzian model. As shown in Fig. S8, the sample is compressed between the bottom of UTGS-based cantilever and the substrate. Then the young's modulus of the sample can be calculated by the following equations:

$$D_f = d_c + d_s \quad (1)$$

$$F_f = kd_c \quad (2)$$

$$F_f = \frac{4}{3}\frac{E}{1-\gamma^2}R_s^{\frac{1}{2}}d_s^{\frac{3}{2}} \quad (3)$$

In equation (1), D_f is the fixed displacement of the micro-Z stage controller in z direction, d_c is displacement of the cantilever which is measured by the Wheatstone bridge circuit detection system when the micro-Z stage controller moves upwards causing the cantilever to make an indentation in the sample, d_s is the indentation depth of the sample ($d_s = d_1 + d_2$). In equation (2), F_f is the force applied to the sample by the cantilever, which is calculated through the cantilever spring constant (k) and its displacement. In equation (3), γ represents the Poisson's ratio of the sample (0.5), R_s is the radius of the sample. Then Young's modulus (E) can be determined.

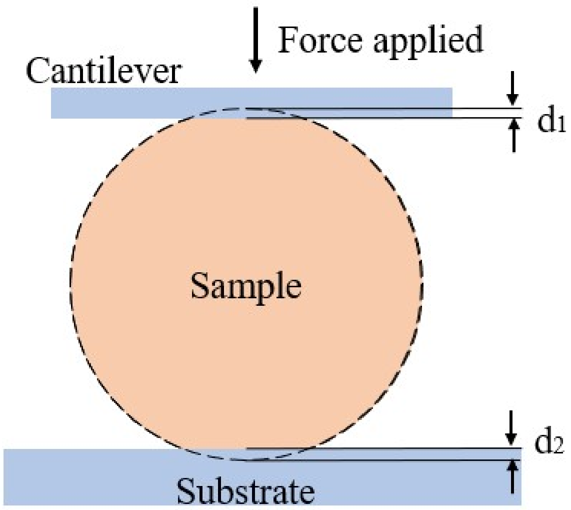

Fig. S8. Schematic diagram of the sample young's modulus measurement by the UTGS-based cantilever.

Reference

[1] Y. Yuan, Y. Yalikun, S. Amaya, Y. Aishan, Y. Shen, Y. Tanaka, *Sensors Actuators A Phys.* **2021**, *321*, 112604.

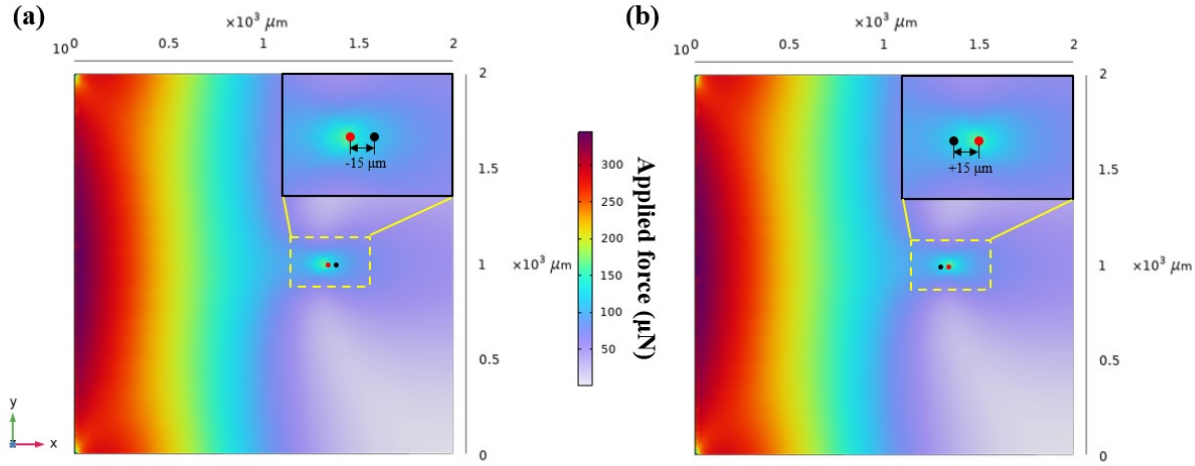

Fig. S9. Simulation results of the applied force (displacement is 10 µm) performed by COMSOL: (a) The position (red dot) of the applied force is -15 µm in the X-axis direction from the specified position (black dot). (b) The position (red dot) of the applied force is +15 µm in the X-axis direction from the specified position (black dot).