Supporting Information

Ultrathin Nanofibrous Membranes Containing Insulating Microbeads for Highly Sensitive Flexible Pressure Sensors

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Figure S1. Measurement setup. The pressure sensor was fixed to a pressure test stand and measured force and capacitance data were recorded simultaneously using a PC.
Figure S2. Microbead-incorporated polyvinylidene fluoride (PVDF) nanofibers were fabricated on aluminum foil using an electrospinning process. The electrospinning times were 5, 10, 20, and 60 min, resulting in membrane coverage areas of 26, 34, 46, and 86 cm², respectively. Nanofibrous membrane thickness did not increase linearly with electrospinning time; instead, nanofibers were dispersed to the periphery of the collector at longer times due to weakening of the electric field strength with increasing coverage in the center of the collector.
Figure S3. SEM micrographs show the membrane surface morphology during pressure testing. a) A 100-kPa pressure was applied while the nanofiber/microbead membrane was held at a temperature slightly below the melting point of PVDF. This fixed the morphology of the compressed film, allowing it to be accurately imaged. As the overall thickness of the film decreased, some beads remained deep in the film. b) After pressure testing up to 150 kPa, the beads remained intact, while the nanofibers at the contact interfaces were slightly damaged.
Figure S4. Pressure-response curves are shown for pressure sensors composed of PVDF nanofibrous membranes without microbeads. Membranes electrospun for 20 min exhibited relatively low sensitivity over the entire pressure range. Increasing the electrospinning time increased the effective film thickness with only minimal improvements in sensitivity.
Figure S5. Pressure sensor composed of nylon films and microbeads. a) SEM micrograph of the nylon layer surface. b) Pressure-response curve of the pressure sensor.
Figure S6. The hysteresis of nanofiber/microbead pressure sensors is shown at various scanning rates. Hysteresis loops up to 40 kPa were similar among slow, normal, and fast pressing speeds. The loop acquired at the fast speed shows some distortion due to fewer sampling points in the test.
**Figure S7.** a) and b) show that response and relaxation times upon loading and unloading, respectively, were less than 10 ms.
**Figure S8.** Surface damage of the electrodes is shown after being scratched by a cotton swab. Repeated scratching with cotton swab were conducted to evaluate the resistance of the strong shear forces on the electrodes. Both samples were prepared as 2 mm × 0.5 mm rectangles and scratched until the resistance stabilized. The sample without post-annealing showed severe surface damage and resistance increase after scratching. However, the post-annealed sample did not show much damage, so as the resistance.
**Figure S9.** a) and b) show the recovered capacitance of nanofiber/microbead pressure sensors during periodic bending-unbending tests; the bending radii were 13 and 27.5 mm, respectively. The scale bar is 20 mm.
Figure S10. A photograph showing a prototype hand-made sensor array signal collection system.