A Stretching/Bending-Insensitive Flexible Pressure Sensor with Carbon Nanotube-PDMS

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Flexible pressure sensors have many successful applications in personal electronic devices, artificially intelligence, and industrial production applications[1]. Despite the good performance and high flexibility, the measurement of pressure under dynamic deformation has remained difficult because the sensing properties vary significantly as a result of the strains induced by mechanical deformation (such as stretching, bending, twisting and wrinkling)[2]. Here, we develop a flexible pressure sensor utilizing an interlocking system based on vertically aligned carbon nanotube (VACNT) carpets on Polydimethylsiloxane (PDMS) substrate, fabricated using a facile fabrication process. Our fabrication technique ensures high flexibility of VACNT-PDMS structure, which enables a relatively consistent electrical conductivity and resistance under varied strains at a constant pressure.

To fabricate flexible substrates with embedded VACNTs, we synthesized VACNTs using atmospheric-pressure chemical vapor deposition (APCVD) and transferred them onto partially cured PDMS. We optimized the curing condition of PDMS, where the partially cured PDMS was tacky but not fully wet. The grown VACNTs were then placed onto partially cured PDMS and the tips of CNTs were partially immersed into PDMS. During the curing process, the tips of CNTs were eventually wetted by partially cured PDMS and the Si/SiO_2 substrate was successfully peeled off from VACNT-PDMS structure after PDMS is fully cured. The VACNT structures are vertically aligned in general, but interwoven at an individual level. Therefore the VACNT-PDMS structure can still have a good electrical conductivity under stretching/bending deformations. After stacking two VACNT-PDMS structures face-to-face, a deformation is induced by an external pressure, and the interconnection between carbon nanotubes can be converted into a different resistance signal. We applied a constant compression strain rate (0.5 inch/min) on the pressure sensor and unloaded at the same rate when the load reached 1N (11.5 kPa), 2N (23 kPa), 5N (57.7 kPa), and 10N (115.5 kPa). The load at each step is shown in Figure 1 (b) and the corresponding current (the voltage is 0.8V) is shown in Figure 1 (c). The rate of change of current was symmetric during loading and unloading, suggesting that the structure has a good reversibility. In addition, the VACNT-PDMS structure was sustained various stretching/bending strains: The pressure sensor was stretched to 200% and bent up to 180˚, while the resistance was consistent up to 50% stretching and 180˚ bending under a constant pressure.

As next steps, the relationship between applied pressures and resistance changes will be fully characterized at various pressure and strains (stretching/bending at different frequencies under different temperatures and humidity values). The cyclic testing of flexible pressure sensor will also be performed to ensure the durability. The sensitivity will be optimized by patterning the VACNT carpets.

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[1] Zsang, Yaping, et al. Materials Horizons 2.2 (2015): 140-156.
[2] Lee, Sungwon, et al. Nature nanotechnology 11.5 (2016): 472-478.

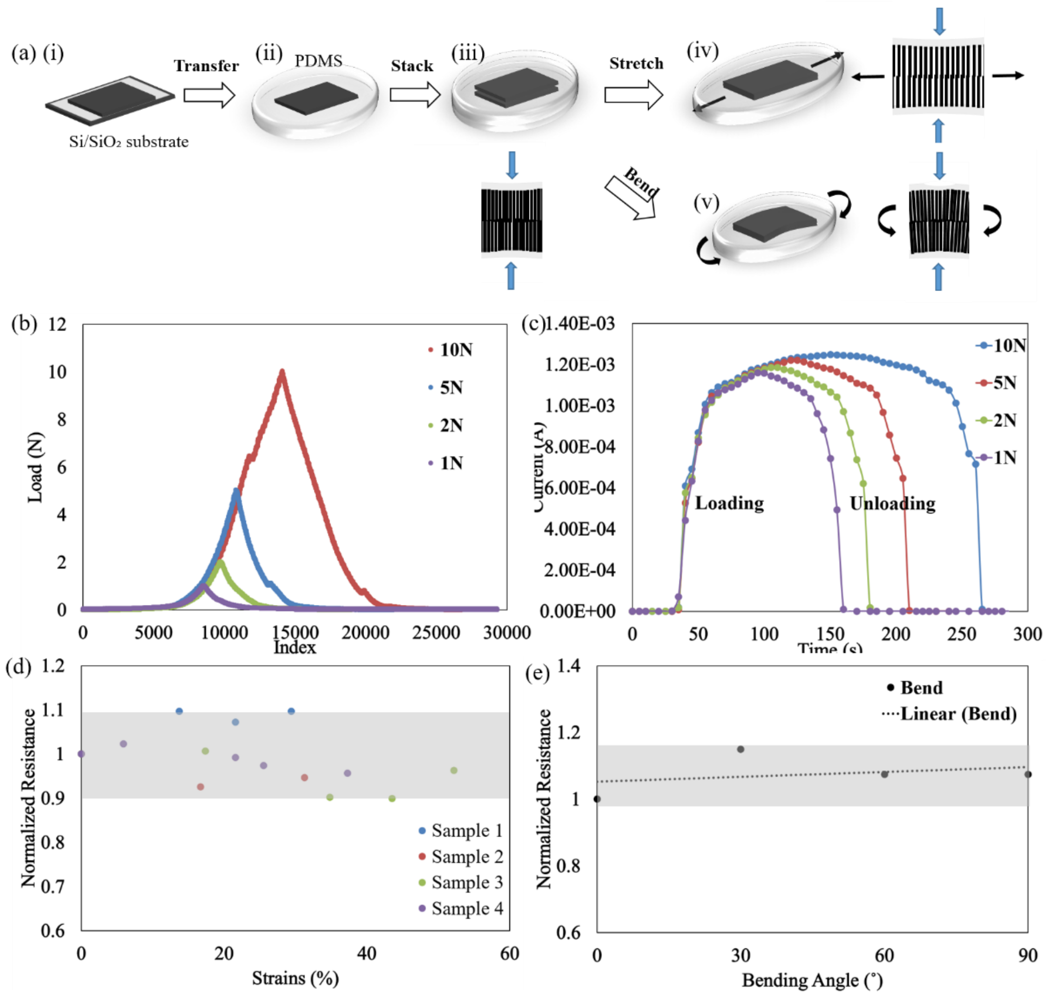

Figure 1. (a) Schematic of fabrication process of flexible pressure sensors. (b) Load change at a constant strain rate during loading and unloading. (c) Current change during loading and unloading. Normalized resistance under different stretching strains (d), and bending angles (e).