

## Supplementary material-Contact electrification

By using Kelvin probe force microscope, the surface potential values of polymer materials can be mapped, and the surface morphology and surface potential of materials can be observed simultaneously. The surface potential diagram of PDMS substrate before and after electric contact is shown in Figure 1<sup>19</sup>. The left side shows a two-dimensional projection, and the right side shows a three-dimensional diagram. The color level of all images is adjusted to -1~ 1V, and the scanning area is 4.5 mm × 4.5 mm. Faraday cup is used to measure the net surface charge density of PDMS before contact charging is 0.005 nC/cm<sup>2</sup>, and the surface potential distribution of PDMS at this time is shown in Figure 1 (a). As can be seen from the figure, the charge is evenly distributed on the surface of the substrate. When PDMS substrate is separated after contact with another PDMS substrate, the net surface charge density of PDMS is -0.2 nC/cm<sup>2</sup>, and the surface potential distribution is shown in Figure 1 (b). As can be seen from the figure, the charge distribution on the surface of the substrate is also very uneven, showing a random "Mosaic" distribution of positive and negative charges. When PDMS substrate is separated after contact with a PC substrate, the net surface charge density of PDMS at this time is 0.16 nC/cm<sup>2</sup>, and the surface potential distribution at this time is shown in Figure 1 (c). It can be seen from the figure that the charge distribution on the surface of the substrate is also very uneven, showing a random "Mosaic" distribution of positive and negative charges.

Contact charging is a complex process that involves bond breaking, chemical changes, and material transfer occurring in different regions on the nanoscale. The nanostructural fluctuations on the surface of the material determine the electrification trend observed at the macro level. In terms of components, contact electrification leads to an increase in the signal strength of the oxide. The formation of oxides is the result of the breaking of homolytic and heterolytic bonds and subsequent reactions with atmospheric oxygen and/or water. The detection results of PDMS substrates before contact electrification (gold-plated silicon wafer as background) and PDMS substrates with positive and negative charges after contact electrification (uncharged PDMS substrate as background) using confocal Raman microscopy are shown in Figure 2 (a), and Raman spectra of these regions are shown in Figure 2 (b)<sup>19</sup>. It can be seen from the figure that in PDMS after contact with electricity, SiCH<sub>2</sub>COOH peaks at 1642 cm<sup>-1</sup>, 1710 cm<sup>-1</sup> and 1730 cm<sup>-1</sup> (marked as \*), And the peak of R-COOH (where R is Si

or C) between  $1730\text{ cm}^{-1}$  and  $1830\text{ cm}^{-1}$  (labeled +) increased, indicating a chemical change at electrical exposure.

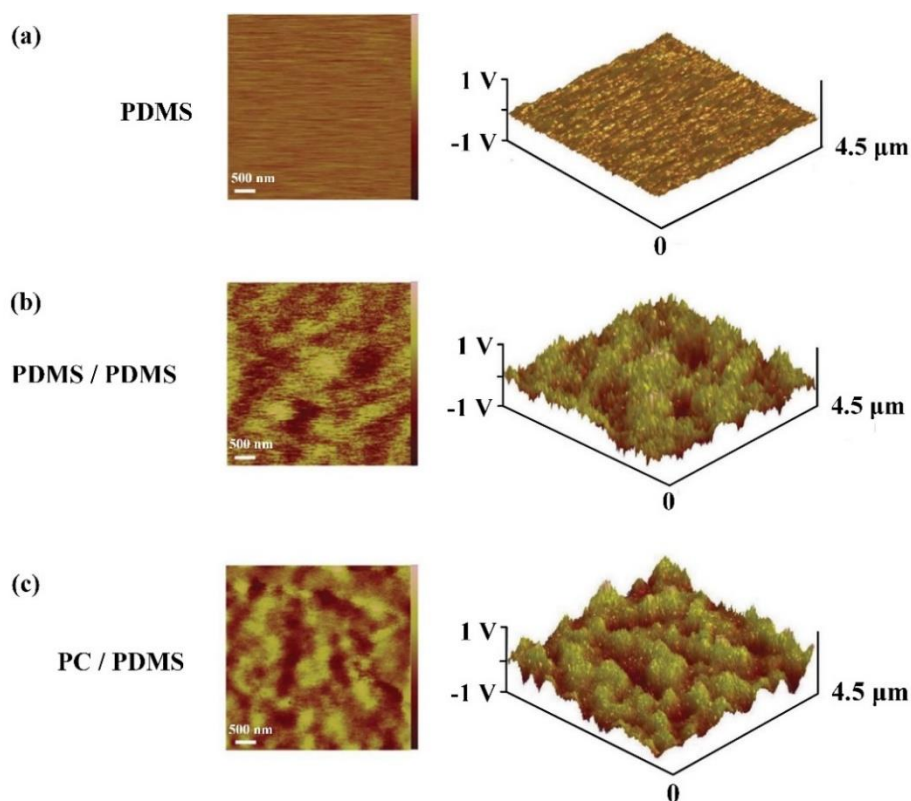


Figure 1 Surface potential map of materials before and after contact electrification<sup>19</sup>

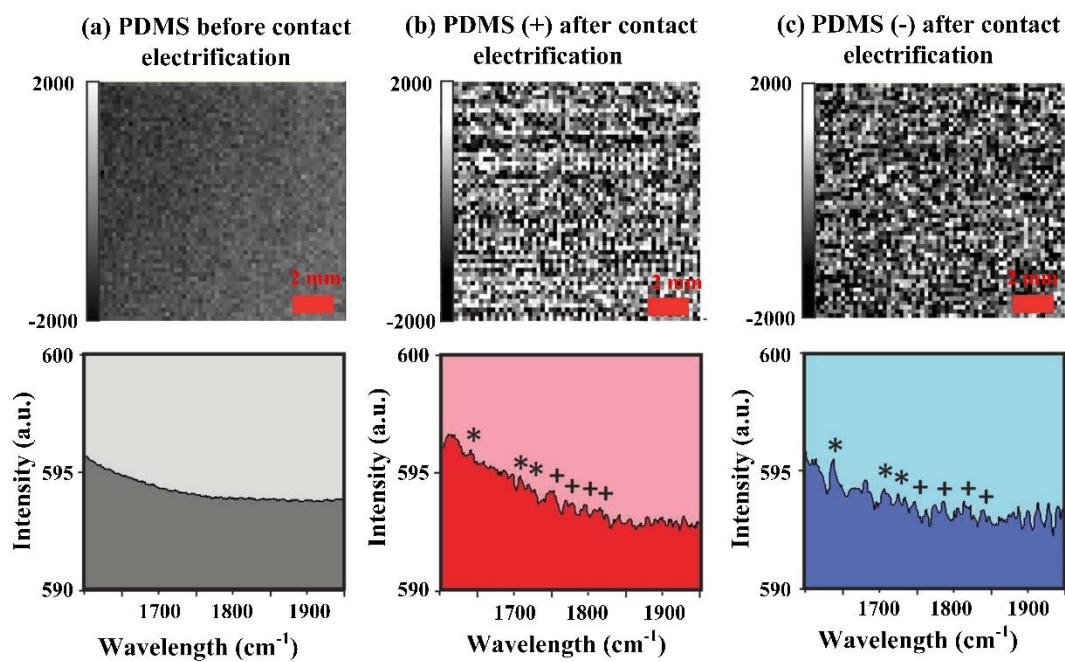


Figure 2 Raman images and Raman spectra of materials before and after contact electrification<sup>19</sup>

PDMS contain Si but do not contain F, PTFE contains F but do not contain Si. PDMS substrate was separated after contact with PTFE substrate, and the X-ray photoelectron spectra of the contact surface were shown in Figure 3<sup>19</sup>. In the spectra of PDMS after contact, when the binding energy is 690 eV, there is a peak of F 1s. In the spectrogram of PTFE after contact, the Si 2p peak appears when BE is 102.5 eV. The strength of these peaks also increases with the number of contacts between the two polymer materials. These results imply that contact charging is associated with the transfer of material fragments.

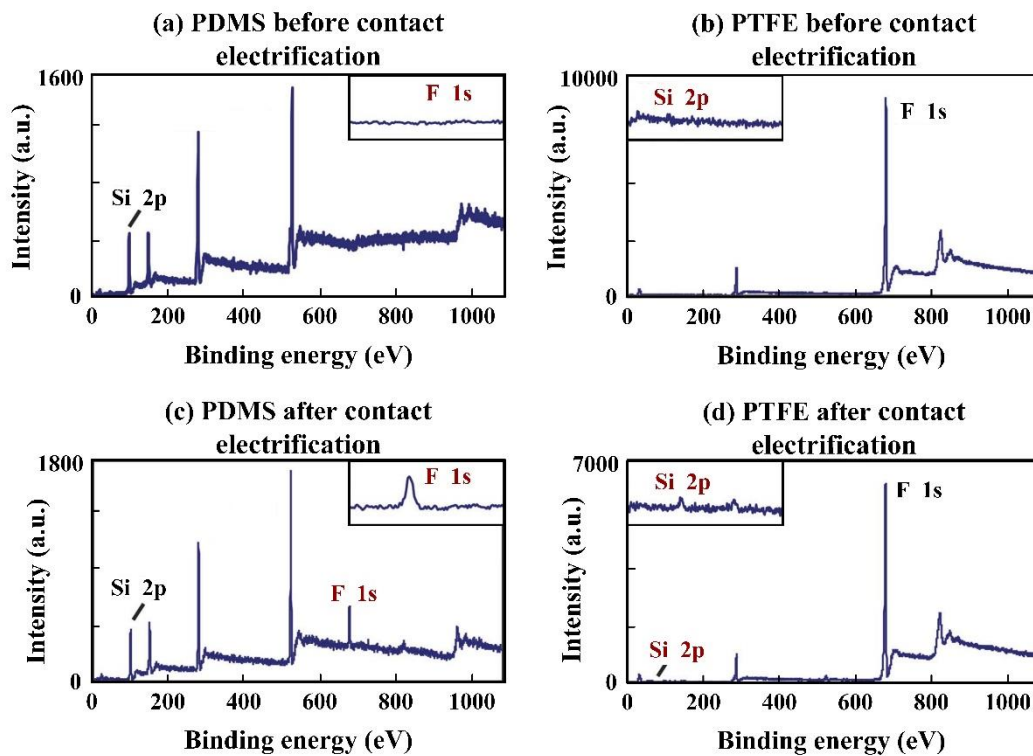


Figure 3 X-ray photoelectron spectroscopy of material contact interface<sup>19</sup>