Electronic Supplementary Material (ESI) for Nanoscale.


**Supporting information**

# Healable, Flexible, Transparent Heaters

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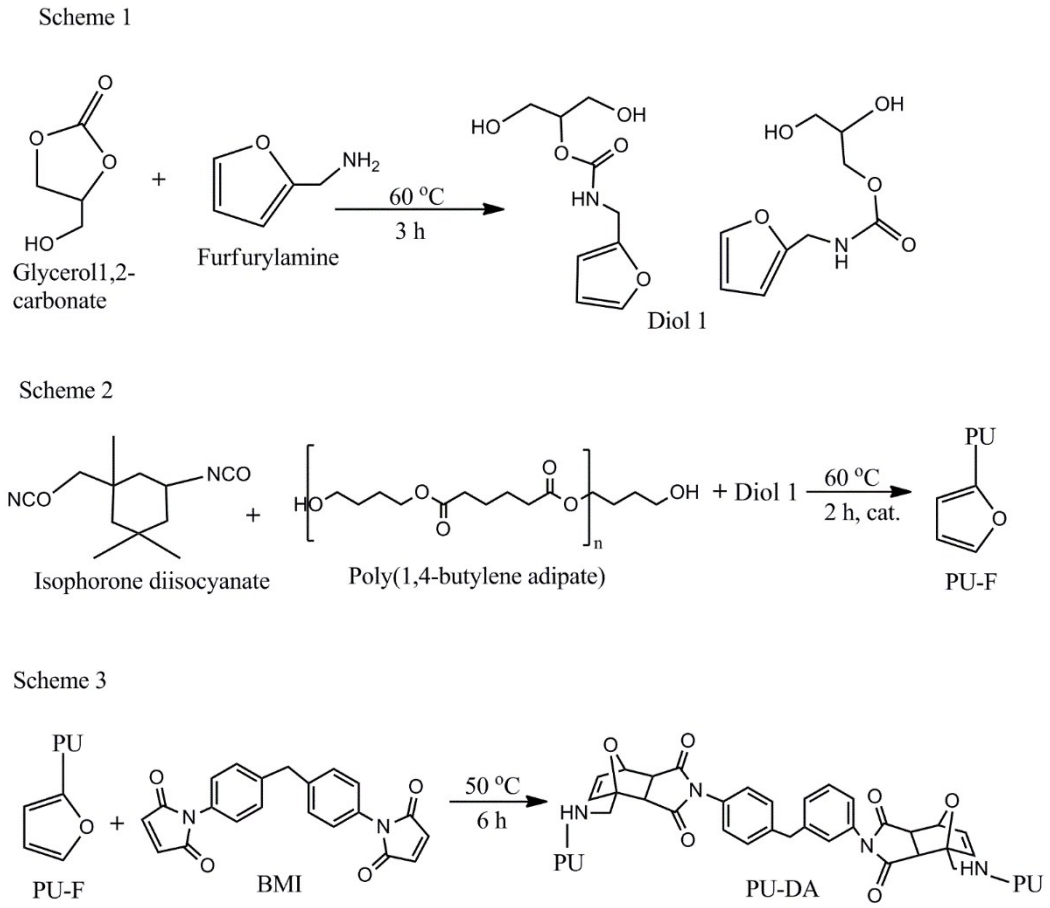



**Figure S1.** The detailed chemical scheme for the synthesis of PU-DA (Healable polymer)

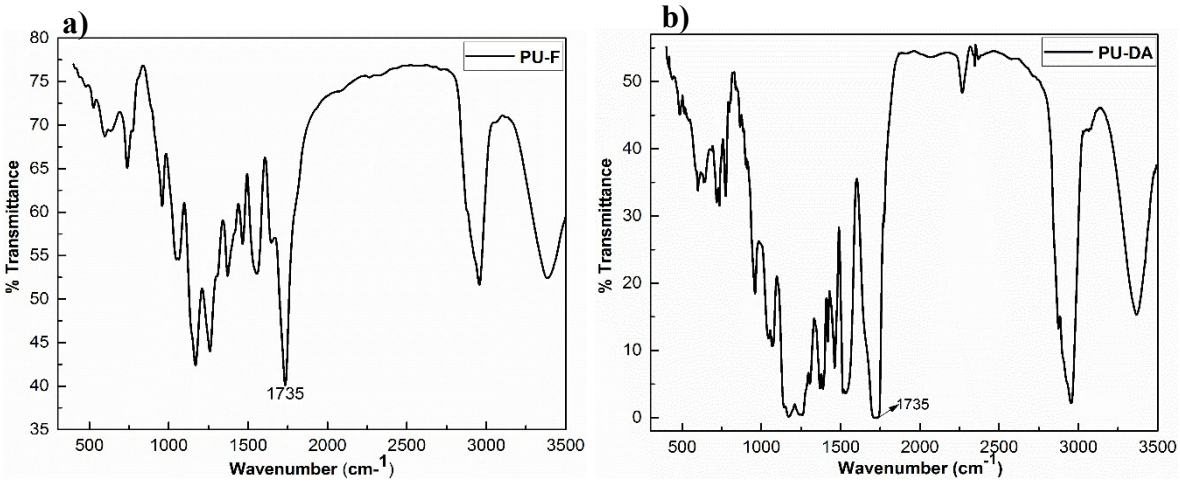



**Figure S2.** (a) FTIR spectra of polyurethane modified with furyl moiety (PU-F). b) FTIR spectra of PU-DA (Healable polymer). The absorption band at 1735 $cm^{-1}$ corresponds to the urethane stretching and indicates that the polymerization was complete.

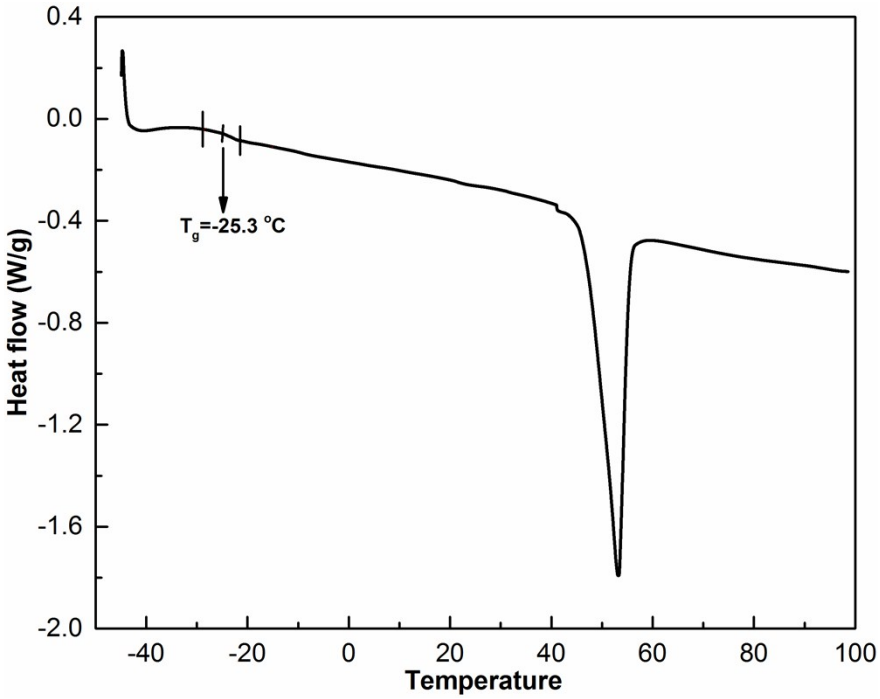



**Figure S3.** DSC of the healable polymer (PU-DA). The glass transition temperature (Tg) of the polymer is -25.3 °C

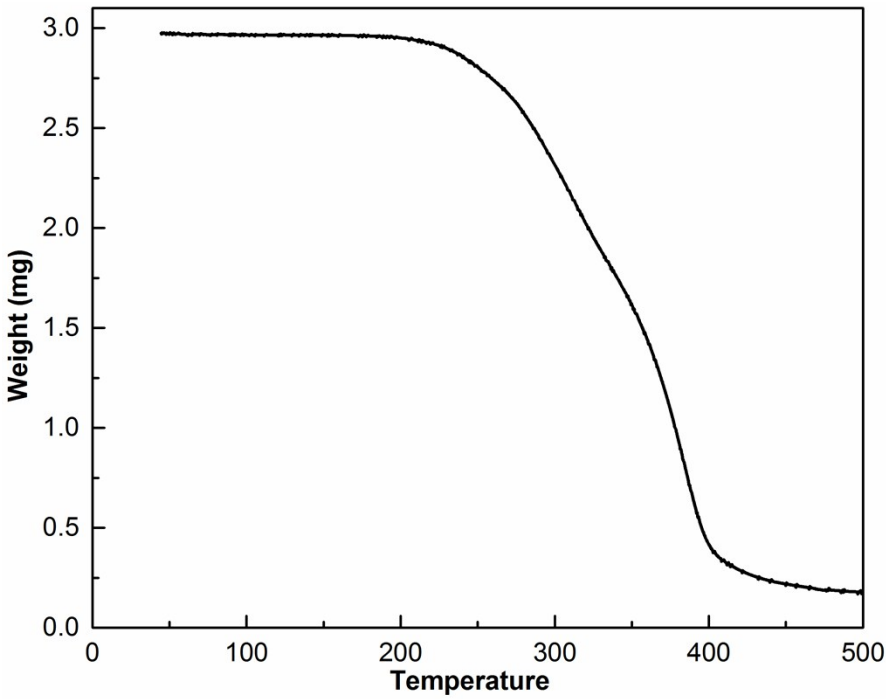
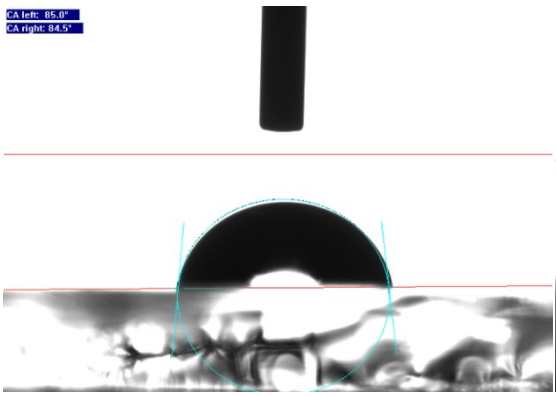
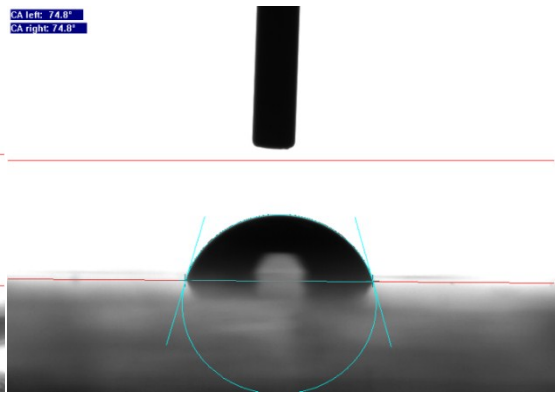


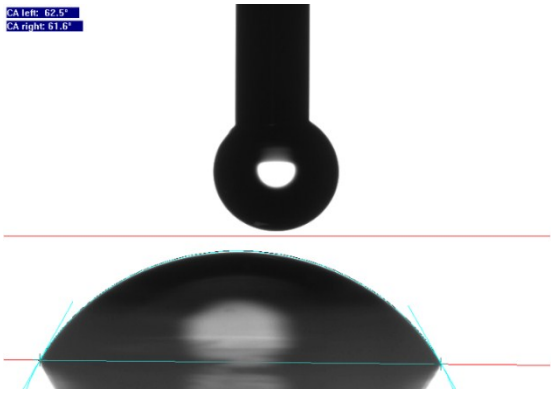

**Figure S4.** TGA curve of the healable polymer. The working temperature of this polymer is below 220 °C because the weight loss of the polymer starts from the temperature above 200 °C.



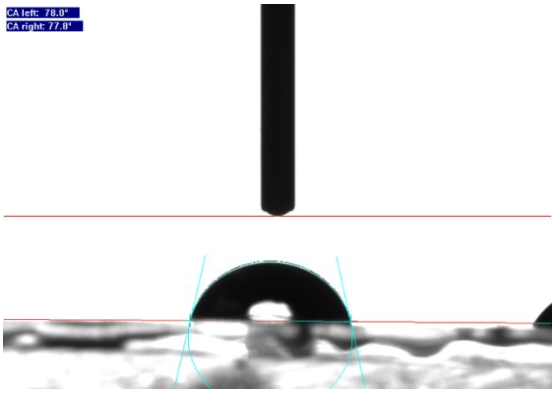

Unmodified with APTES solution
Contact angle- 84.75°



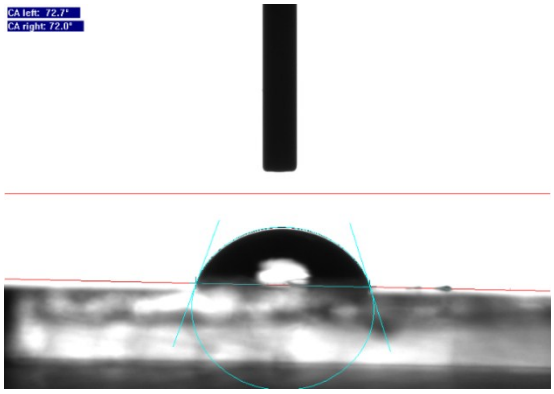

Modified with APTES solution kept for 24 h
Contact angle- 74.8°
Concentration of APTES- 5 mM



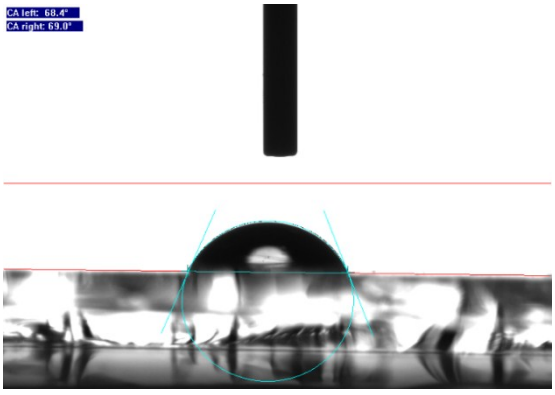

Modified with APTES solution kept for 48 h
Contact angle- 62.03°
Concentration of APTES- 5 mM




Modified with APTES solution kept for 2 h
Contact angle- 77.9°
Concentration of APTES- 15 mM

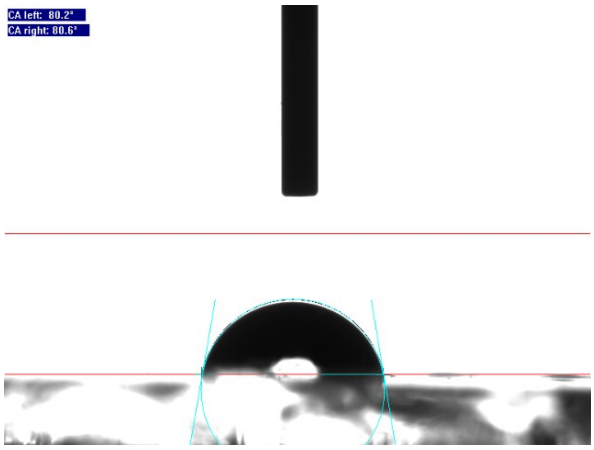



Modified with APTES solution kept for 4 h
Contact angle- 72.35°
Concentration of APTES- 15 mM

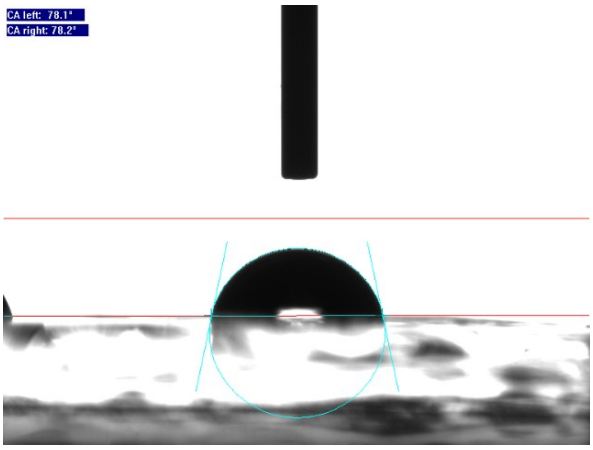



Modified with APTES solution kept for 6 h
Contact angle- 68.70°
Concentration of APTES- 15 mM

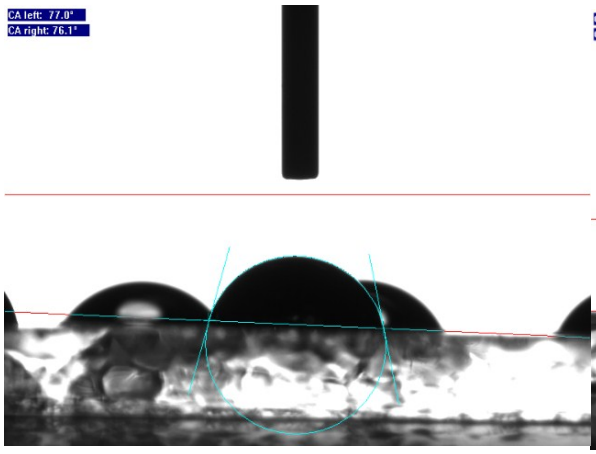
**Figure S5.** Change in contact angle of the samples with 5 mM and 15 mM concentration of APTES solution at different time. The change in contact angle with 5 mM APTES solution is not much effective and the contact angle for 15 mM APTES solution after 24 h was shown in Figure 1(c).



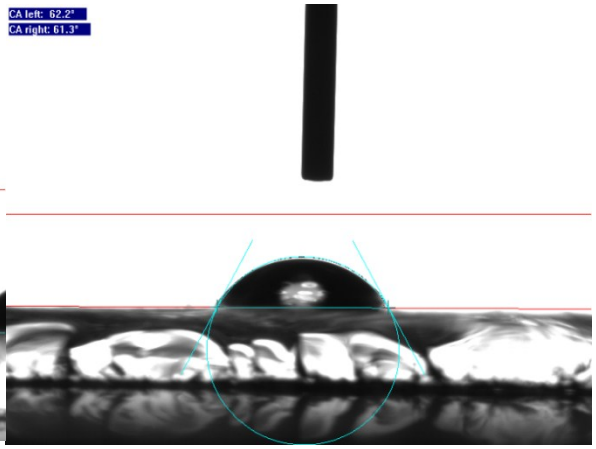

Modified with APTES solution kept for 2 hr.
Contact angle- 80.4°
Concentration of APTES- 25 mM




Modified with APTES solution kept for 4 hr.
Contact angle- 78.15°
Concentration of APTES- 25 mM




Modified with APTES solution kept for 6 hr.
Contact angle- 76.55°
Concentration of APTES- 25 mM




Modified with APTES solution kept for 24 hr.
Contact angle- 61.75°
Concentration of APTES- 25 mM

**Figure S6.** Change in contact angle of the samples with 25 mM concentration of APTES solution at different time

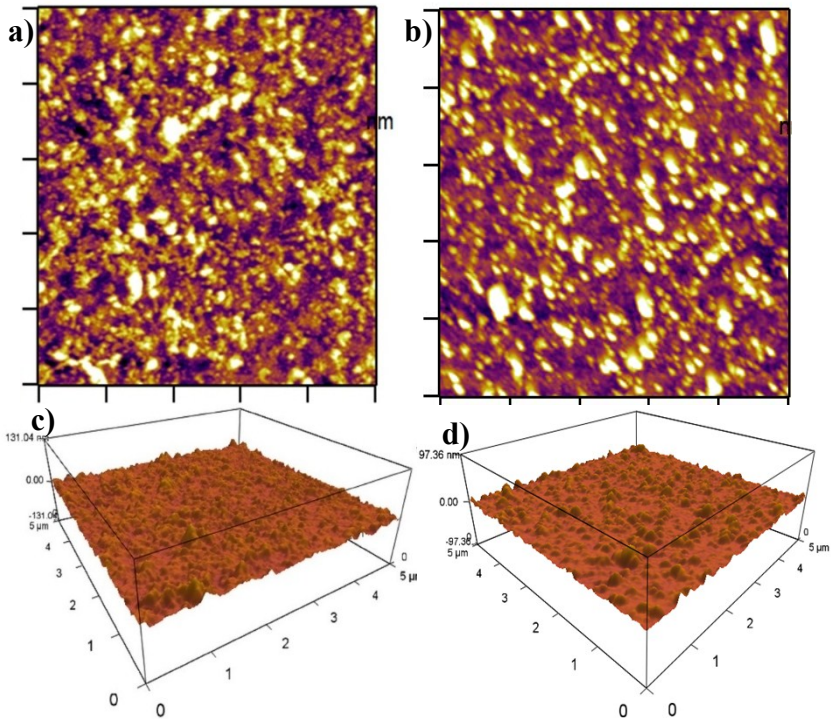



**Figure S7.** AFM images in 2D and 3D with and without APTES treatment. The RMS value of unmodified and modified sample was 4.8 nm and 4.3 nm respectively. (a) & (c) were the images of the sample without APTES treatment and (b) & (d) were the images of the sample with 15 mM APTES treatment.

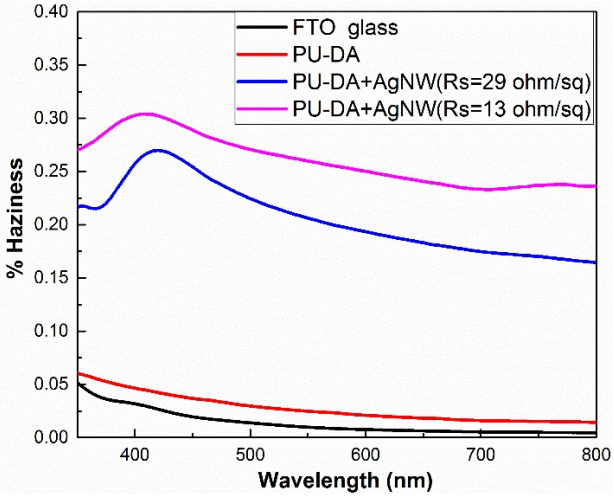



**Figure S8:** Haze factor of the PU-DA polymer with and without silver nanowires.

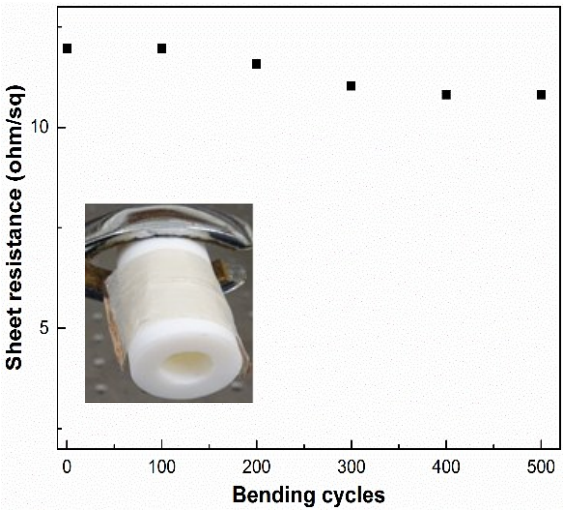



**Figure S9**. Sheet resistance change of the sample with the number of bending and unbending cycle/times. The image inset in the bending-unbending graph shows the sample was wrapped around a 20 mm diameter cylinder

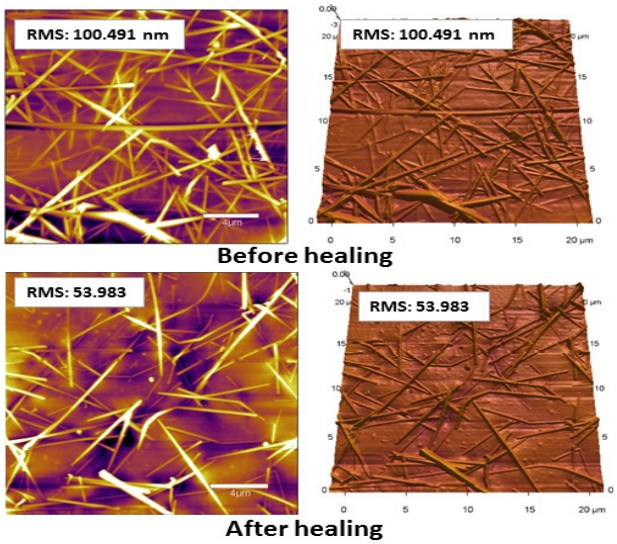



**Figure S10**. Surface roughness of the transparent electrode (TE) before and after healing. The surface roughness of the transparent electrode before and after healing was 100.491 nm and 53.983 nm respectively.

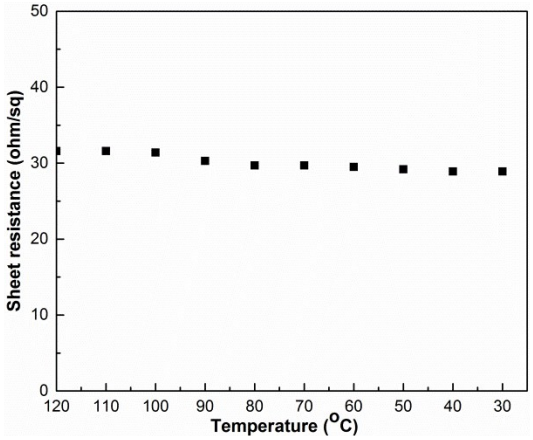


**Figure S11.** Sheet resistance change of a healable heater film with change in temperature. The film heater was cooled from 120 °C to RT and for every decrease in temperature the film was kept for 2 min at that temperature.

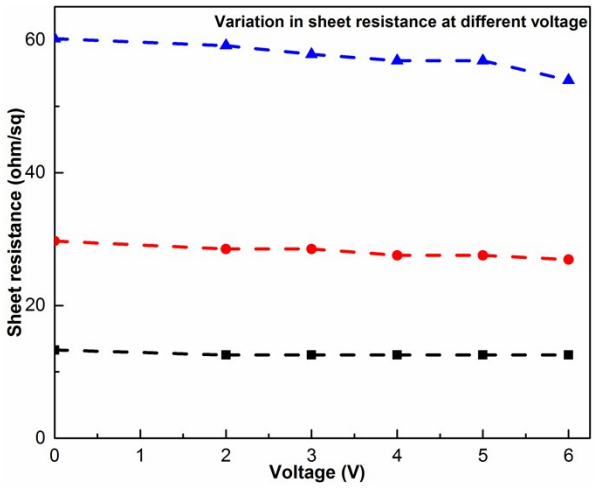



**Figure S12.** Variation in sheet resistance at different voltage for different transparent healable heater based on AgNWs.

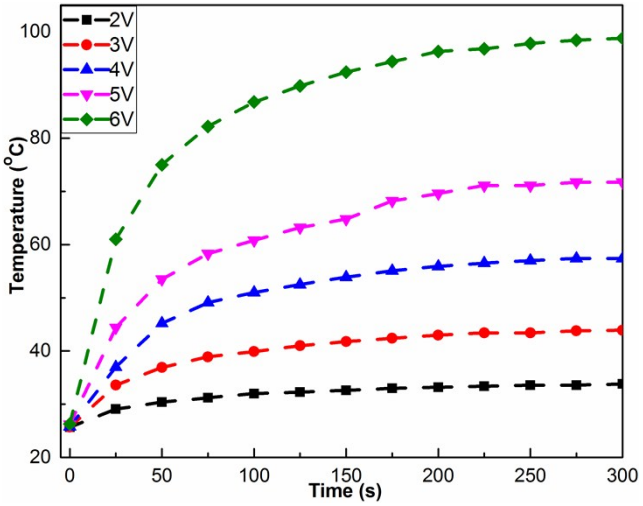



**Figure S13.** Time – dependent temperature profiles at different input voltage with specified sheet resistance of 29.7 Ω /□.

**Table S1.** Comparison with other healable transparent electrode:

| Material | substrate | $T_{total}$ (%) | $R_{sheet}$ (ohm/sq) | Area ($cm^2$) | Healing temp (°C) | References |
|---|---|---|---|---|---|---|
| AgNWs/PU-DA | glass | 77 | 13 | 3.9*1.4 | 120 | Present work |
| Cu NWs/DA-PU | glass | 66.5 | 22.3 | 1*2 | 120 | X. Zhang et. al, Materials Research Bulletin, 2017, 90, 175-181 |
| Au@PCLx/rGO/Ag | Al foil | -- | 11.5 | 1*2 | 532 nm laser~122 °C | L. Chen et. al, Journal of Materials Chemistry C, 2016, 4, 10018-10025 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RFGO/PU | On different pattern | -- | -- | 3*0.2 | 800 W microwave oven for 5 min then 2 h at 70 °C | J. Li, G. Zhang, R. Sun and C.-P. Wong, Journal of Materials Chemistry C, 2017, 5, 220-228. |
| PEDOT/AgNW/FM−DA | PET | 78 | 15 | 0.7*1 | 100 | J. Li et. al, ACS Applied Materials & Interfaces, 2015, 7, 14140-14149 |
| AgNW/PDMS-CPU | glass | 91.1 | 61.5 | -- | 120 | D. H. Lee et.al, ACS Applied Materials & Interfaces, 2016, 8, 8129-8136 |
| AgNWs/MDPB–FGEEDR | glass | 50 | 9.5 | 8*12 | 110 | C. Gong et.al, Adv. Mat., 2013, 25, 4186-4191 |