<div align="center">**Supporting Information**</div>

Microwave-Assisted Immobilized Silver Nanowires on Arbitrary Substrates: An Eco-Friendly Technique for the Next-Generation Transparent, Flexible and Robust Electronics

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S1- Synthesis of silver nanowires (150-ml scale)

Ag NWs were synthesized in solution as follows, 50 mL of ethylene glycol (Merck) in a glass flask was preheated in an oil bath at 151.5 °C for 1 h under continuous magnetic stirring. The reagent solutions of $CuCl_2$ (Merck), polyvinylpyrrolidone (PVP, Sigma-alderich), and $AgNO_3$ (Merck) were prepared in EG during the preheating step. Then, 400 µL of 4 mM $CuCl_2$ solution was added to the flask. After 15 min, 15 mL of 0.147 M PVP was injected into the flask. Finally, 15 mL of 0.094 M $AgNO_3$ solution was added to the flask at the injection rate of 0.5 mL/min using a syringe pump. After 90 min, the color of the reaction solution changed to opaque gray. After nanowire formation, the reaction was quenched by cooling the reaction flask in a water bath at room temperature. Finally, the reaction mixture was diluted with ethanol purified to remove excess reagent after the reaction finished and centrifuged at 4000 rpm for 4 min. The centrifugation process was repeated four times. The collected silver nanowires were redispersed in DI water before being deposited on the substrate.

S2- Graphene CVD growth transferred method

Graphene CVD growth on copper foils left in DI water at room temperature overnight to oxidatively decouple graphene sheet from copper foil. Subsequently, the PVA film was laminated on top of graphene CVD growth film at 110°C by using a commercial hot-roll office laminator (RAYSON LM-600). Then to improve adhesion among graphene sheet and PVA film put them on the hot plate at 110°C for 30 s. Afterward, the copper foil was peeled off from the

PVA film. The graphene sheet is quite transferred to the PVA film and is ready to transfer on the arbitrary substrate. In the following step, PVA-graphene film is placed onto the target substrate and passes through the laminator under the same condition. Subsequently placed on the hot plate at 110°C for 1 min and Coinciding with substrate still on the hot plate white supporting paper was delaminated. Ultimately, to remove PVA film from the substrate, left it into the DI water at room temperature for several hours.

S3- XPS characterization

The chemical functionalization of PI, PI treated by O_2 plasma, and subsequently, CYS grafted was examined by XPS. The corresponding C 1s, O 1s, S 2p, and N 1s regions for the CYS functionalized surfaces are shown in Figure S1. The XPS survey spectrum of PI-CYS shows the presence of C, O, N, and S at the corresponding positions. The results confirm varies in the surface chemistry of substrate after plasma treatment and subsequent CYS grafting. For the C1s spectrum of the pristine PI sample, the prominent peak located at 284.7 eV corresponds to phenyl C=C bonds of ODA structure and the peak at 285.8 eV is related to C–N bonds in PMDA structure. The other two peaks located at 286.3 eV and 288.6 eV are attributed to ether group C_6H_4–O in the ODA unit and carbonyl group C=O in imide cycles of the PDMA unit, respectively [1]. After O_2 plasma, besides a red-shift in the C_6H_4–O bond, the peak intensity is sharper. And this peak disappeared after graft CYS on the surface. The peak related to the C=O bond shows a blue shift with an enhancement in its proportion from 15.94 to 23.84 percent after plasma treatment and is reduced to 10.85 percent after CYS grafting. The S 2p spectrum is shown in Figure S1 and three fitted peaks at 163.4, 164.66, and 167.9 eV are observed. The first two peaks correspond to thiol groups on the surface and can be assigned to electrons ejected from the $p_{3/2}$ and $p_{1/2}$ orbitals, respectively. The peak at 167.9 eV is due to the oxidization of sulfur atoms that may be produced by the native oxygen in DI water in CYS solution. The appearance of the C─S bonds proves that the Sulphur was chemically bonded to the surface [2].
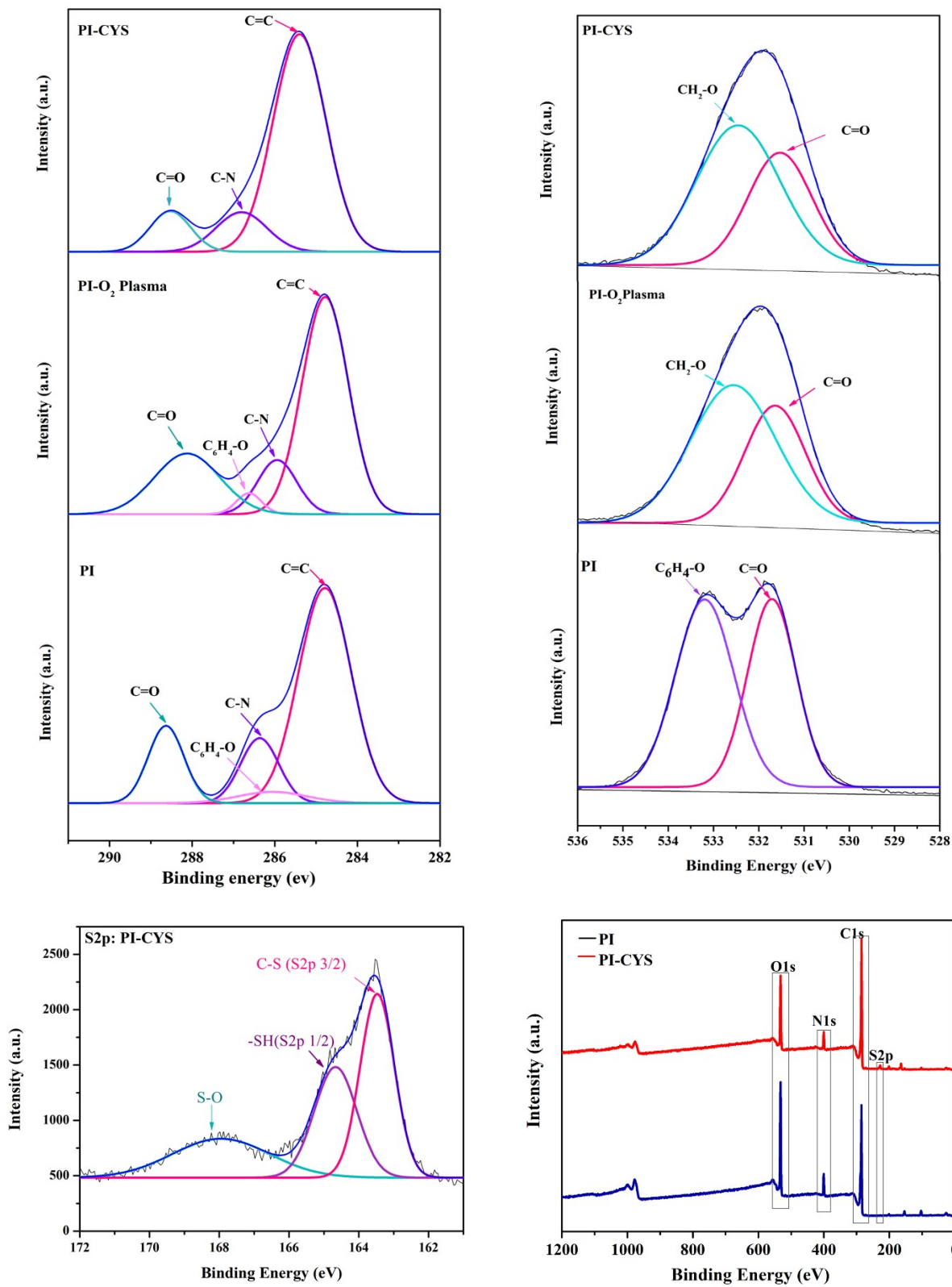
Figure S1. XPS survey spectra of a) C1s, b) O1s, for PI, PI- O_2 Plasma, and PI-CYS c) S2p for PI-CYS, d) XPS survey data for PI, and PI-CYS.

S4- Patterning procedure of AgNWs

The procedure for patterning of AgNWs is depicted in Figure S2. First, photoresist is spun coated on the substrate and patterned by prevalent photolithography process. Afterward, substrate was treated by O_2 plasma subsequently decorated with CYS by applying MW irradiation. Substrate rinsed with ethanol and DI water followed by drying with N_2 gas in order to remove un-grafted CYS. At the next step, AgNWs spun coated on the substrate and left it to dry at room temperature. Finally, fine patterns were appeared by lift-off process.
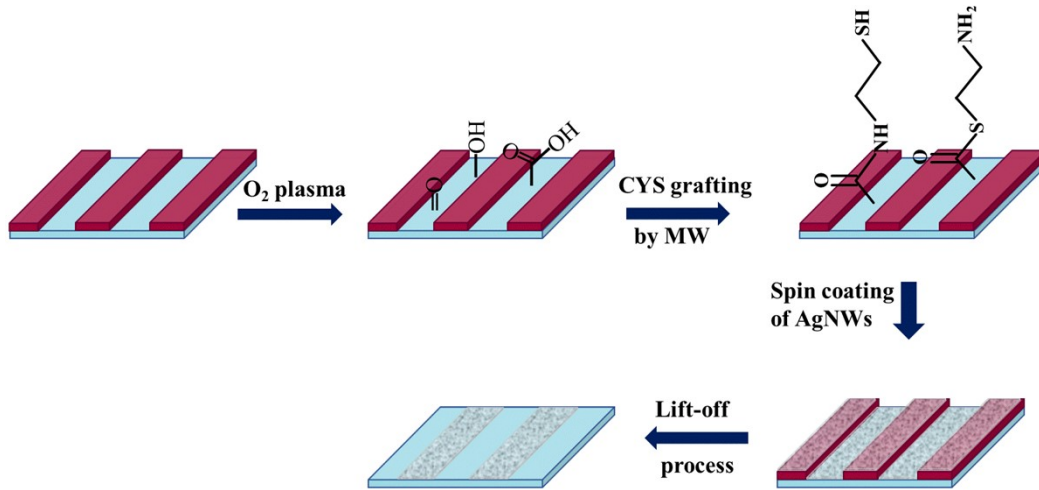
Figure S2. The procedure for patterning of AgNWs.

S5- Four-point probe measurements with van der Pauw geometry

In van der Pauw (vdp) square channel geometry, four contacts are placed at the edges of square as shown in Figure S2. Two sets of measurements are carried out to include horizontal and vertical conduction in the film, consequence in the following groups of resistance (Equation 1 and 2):

Group A (horizontal):
$$R_{12,34} = \frac{V_{34}}{I_{12}}, \quad R_{21,43} = \frac{V_{43}}{I_{21}}, \quad R_{34,12} = \frac{V_{12}}{I_{34}}, \quad R_{43,21} = \frac{V_{21}}{I_{43}} \qquad (1)$$

Group B (Vertical):
$$R_{13,24} = \frac{V_{24}}{I_{13}}, \quad R_{31,42} = \frac{V_{42}}{I_{31}}, \quad R_{24,13} = \frac{V_{13}}{I_{24}}, \quad R_{42,31} = \frac{V_{31}}{I_{42}} \qquad (2)$$

Therefore, the average resistance is calculated for each group by Equation 3 and for:

$$R_A = \frac{(R_{12,34} + R_{21,43} + R_{34,12} + R_{21,43})}{4} \tag{3}$$

$$R_B = \frac{(R_{13,24} + R_{31,42} + R_{24,13} + R_{31,42})}{4} \tag{4}$$

Finally, sheet resistance is calculated using Equation 5.

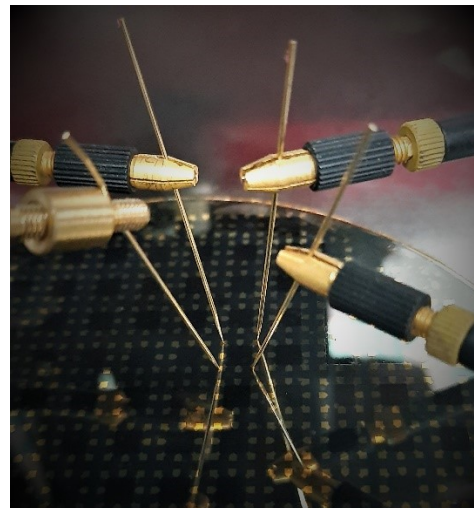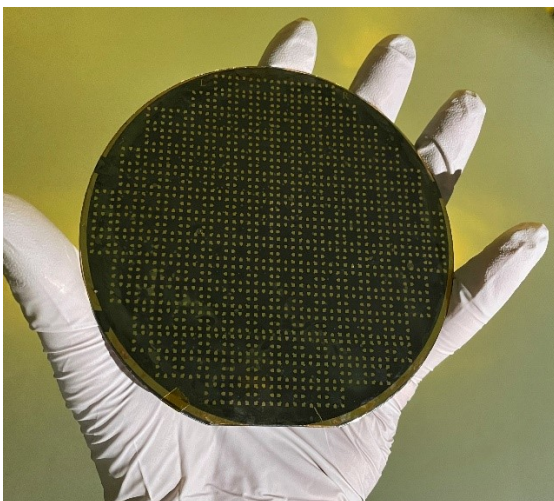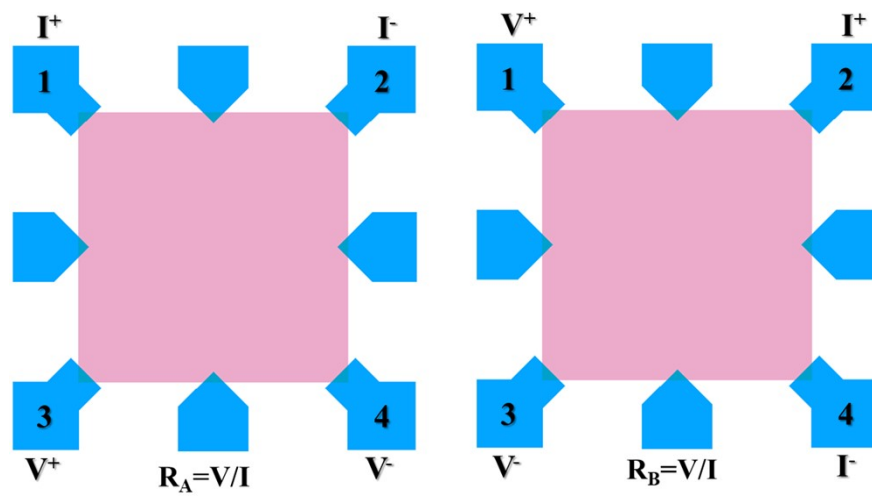$$e^{-\pi R_A/R_{sh}} + e^{-\pi R_B/R_{sh}} = 1 \tag{5}$$

Figure S3. Different van der Pauw square configurations for measuring the sheet resistance of the same device at different gate voltages.
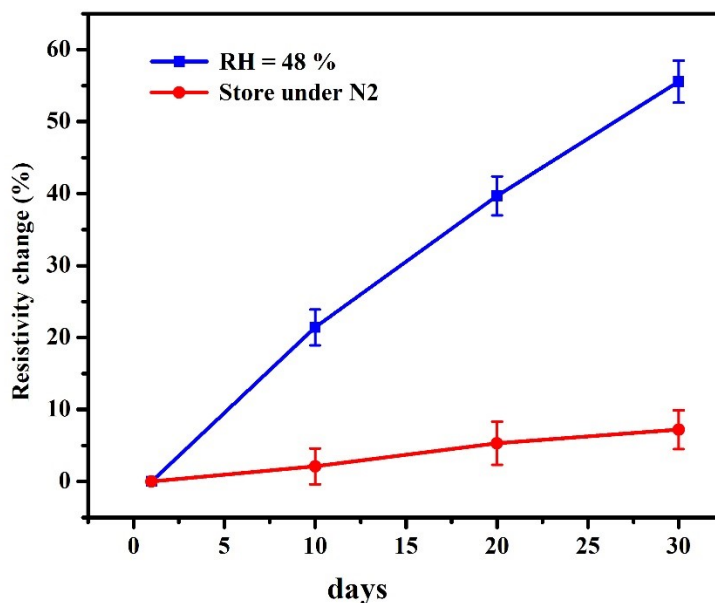
S6- Environment stability of the fabricated film

Figure S4. PET-CYS-NWs (0.3%) conductivity stability at 25°C was stored at two different conditions RH = 48% and under N_2 gas over 30 days.
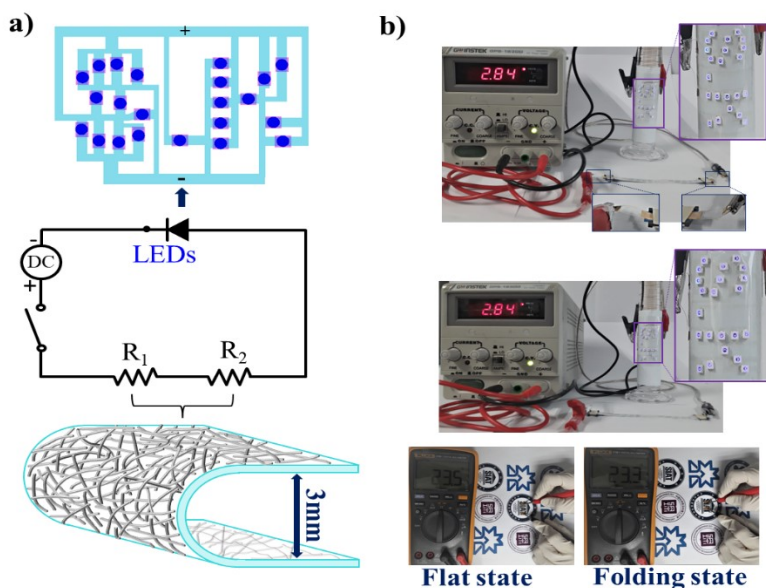

S7- LED array and Electrochemical biosensor

Figure S5. a) The schematic circuit diagrams of the LEDs array, b) The photographs of LEDs with no light emission change of the LEDs connected with two series of NWs resistors at two flat and folding states.
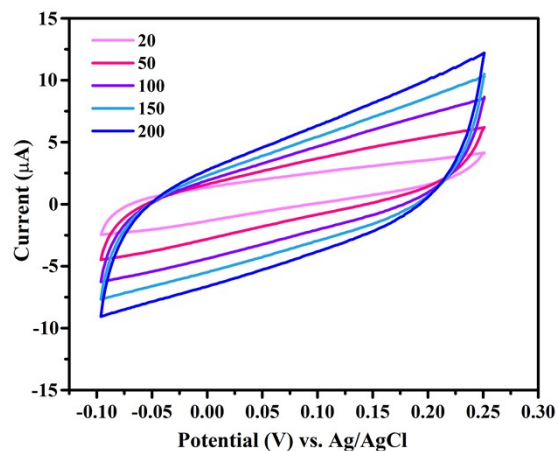
S8- Electrochemical biosensor

Figure S6. Cyclic voltammograms of PET-CYS-NWs at scan rates of 20 to 200 mV/s, in PBS 0.1 M, PH 7.4.

Refrences

[1]   A. Ektessabi and S. Hakamata, *Thin solid films,* vol. 377, pp. 621-625, **2000**.

[2]   Park, M.-S.; Yu, J.-S.; Kim, K. J.; Jeong, G.; Kim, J.-H.; Jo, Y.-N.; Hwang, U.; Kang, S.; Woo, T.; Kim, Y.-J., *Phys. Chem. Chem. Phys.,* vol. 14, no. 19, pp. 6796-6804, **2012**.