Interpenetrating Network of Conductive Hydrogel

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Background

Recently, hydrogels have becoming a promising candidates for the next generation of bioelectronics because of their similarity to biological tissue and their versatility in electrical and bio functional engineering. Bioelectronics interfaces with the human body, including electrical stimulation and recording of neural activity, are fundamental to the rapidly growing fields of neuroscience and engineering, diagnostics, therapeutics, wearable devices and implantable devices. Due to the inherent differences between soft, moist biological bodies and hard, dry synthetic electronic systems, the development of more compatible, efficient and stable interfaces between these two disparate fields is one of the most daunting challenges in science and technology. [1]

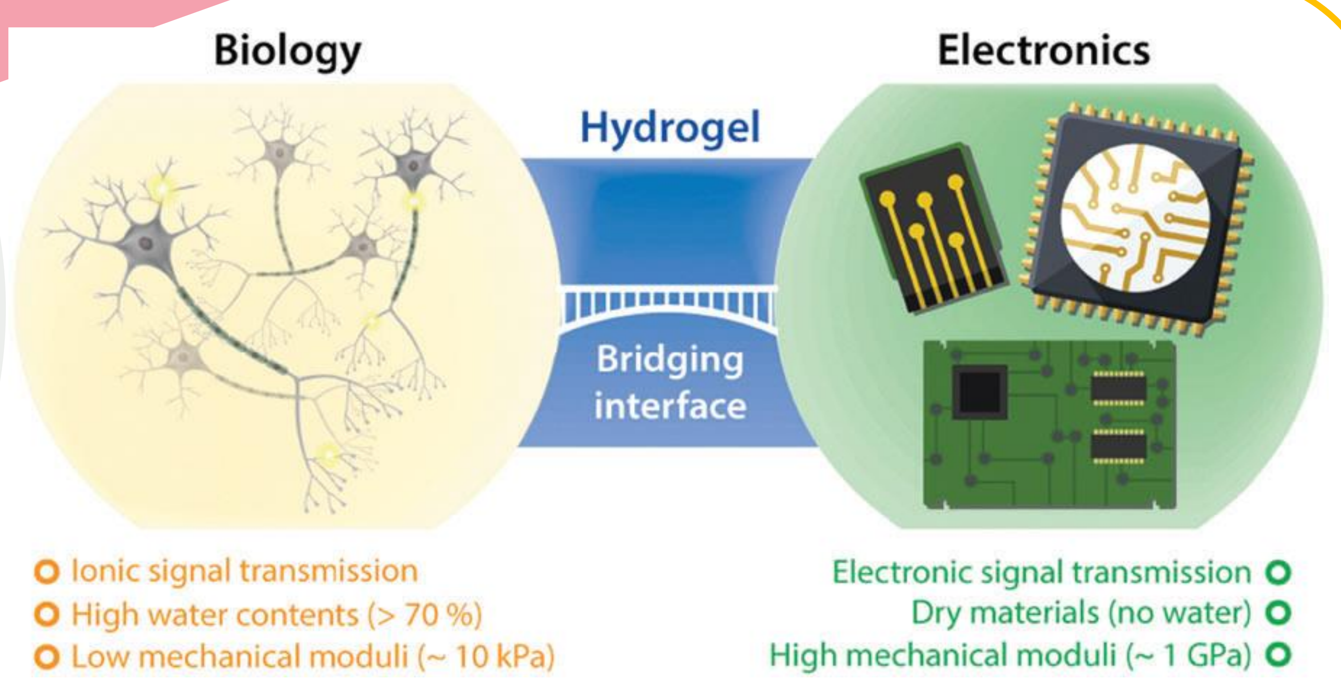

Fig. 1 Hydrogel is the bridge between biology and electronics.[1] Hydrogels have a unique set of properties that can bridge the gap between biology and electronics, offering opportunities for bioelectronic applications.

Methods

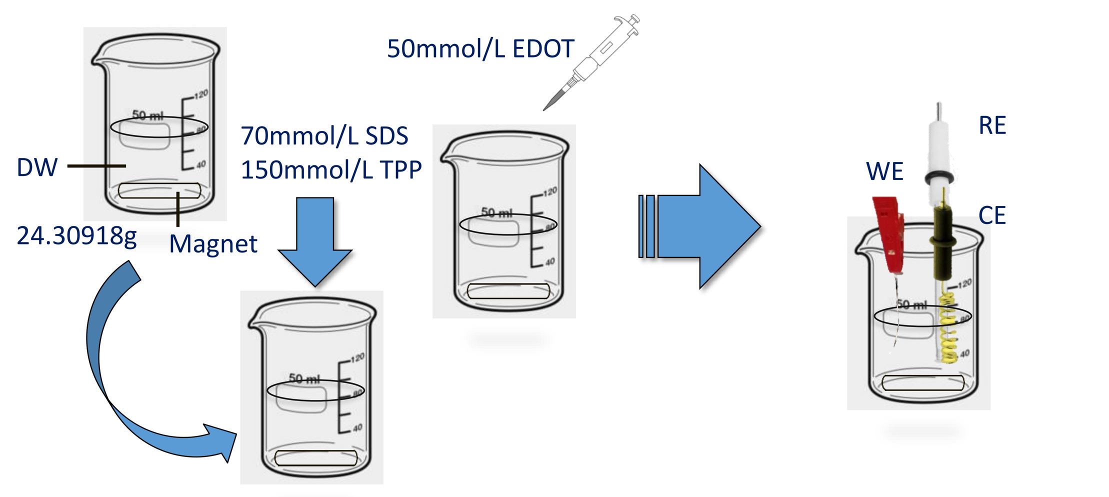

Fig.2 Protocols of electrodeposition.

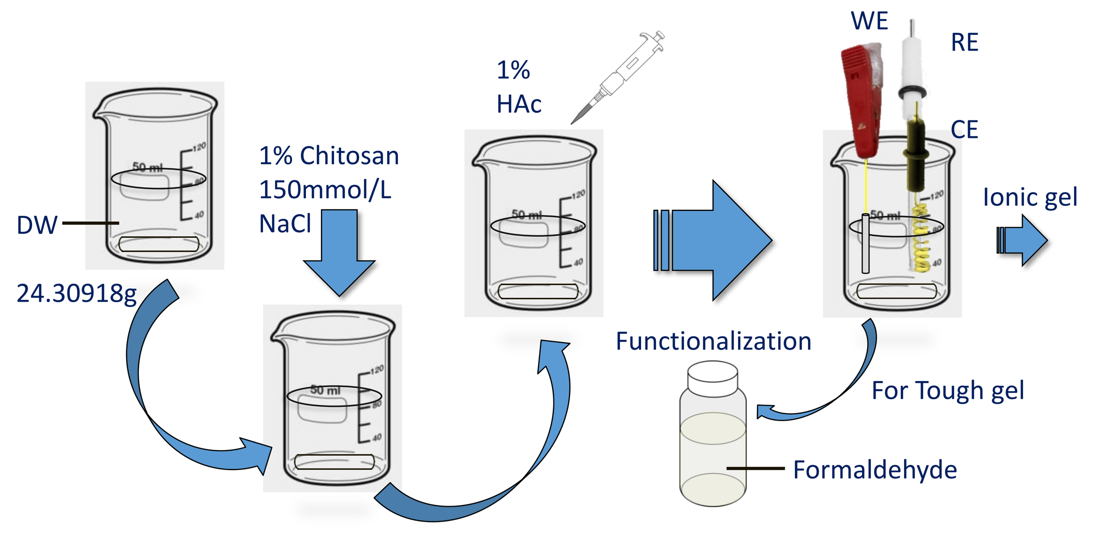

Fig.3 Protocols of TPP release.

The Fig.2 demonstrates the protocols of electrodeposition of EDOT monomers to PEDOT polymer. It gets oxidized and generate charges, where the TPP ions enter to structure. The 1 and 2 steps occurs in the first electrodeposition (1000 pulses in EDOT + TPP solution). The Fig.3, which is the hydrogel generation, in a solution containing chitosan. A negative potential is applied to reduce again the PEDOT structure and release the TPP. The TPP forms ionic bonds between chitosan chains, obtaining the hydrogel.

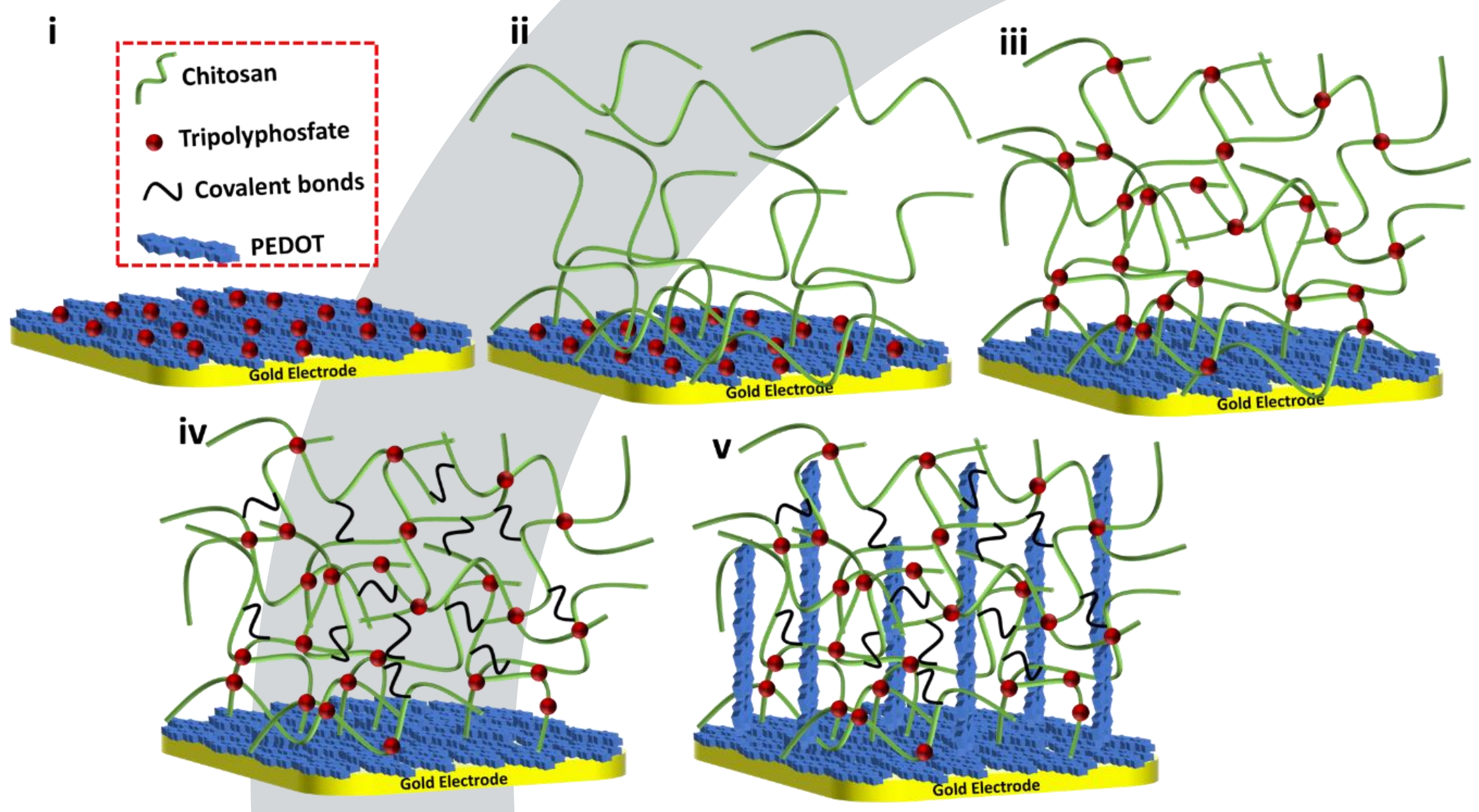

Fig.4 Schematic mechanism representation. 1 is the electrodeposition of PEDOT:TPP (PEDOT doped with TPP), 2 represents it in chitosan solution and 3 after the reduction of PEDOT chains and ionically crosslinking the Chitosan with TPP. 4 is the functionalization in formaldehyde to obtain covalent bounds between the Chitosan chains. 5 is the representation of interpenetrating network of PEDOT inside the Chitosan hydrogel structure.

Results

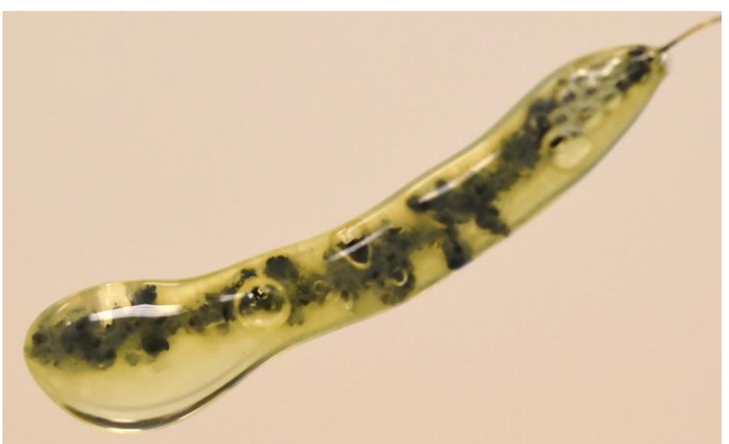

Fig.5 Photo of PEDOT Chitosan hydrogel sample.

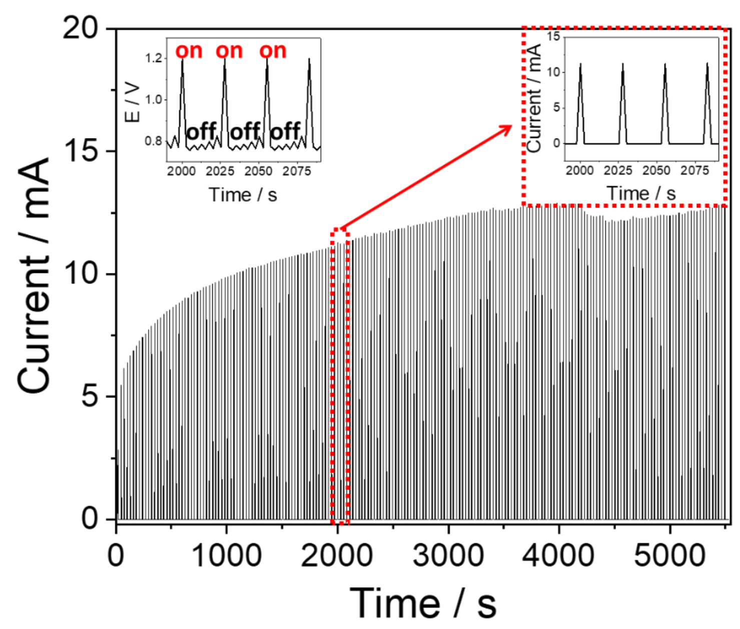

Fig.6 Electrodeposition profile. 1000 pulses at 1.2V.

EIS spectra

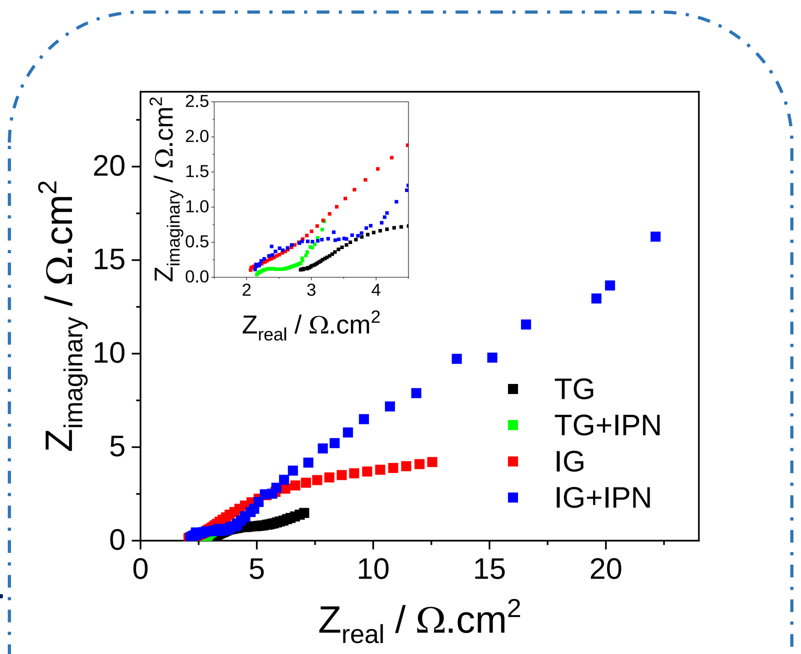

Fig. 7 Nyquist plot.

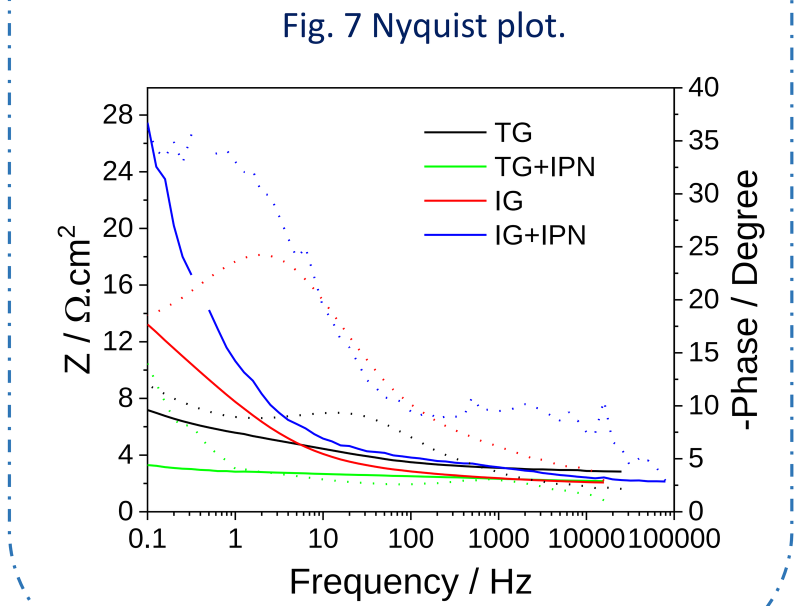

Fig. 8 Bode plot.

$$Q = \int_{t_i}^{t_f} I\,dt$$, Q is charge, I is current, t is time.

For the electrodeposition:

$$Q_{total,1} = Q_{electrodeposition} + Q_{oxidation}$$

For the TPP release:

$$Q_{total,2} = -Q_{reduction}$$

$$\therefore Q_{electrodeposition} = Q_{total,1} - Q_{reduction}$$

Effective surface coverage (Γ) relationship:

$$\Gamma_{PEDOT} = \frac{Q_{electrodeposition}}{n\,F\,A}$$

For the Doping level:

$$n_{TPP} = \frac{Q_{reduction}}{n\,F}$$

$$Doping\ level = \frac{n_{TPP}}{n_{PEDOT}} \times 100$$

The conductivity σ can be calculated by using:

$$\sigma = \frac{l}{R\,A}$$

l is the thickness of the material (cm), R is the resistance (Ω) and A is the area (cm2).

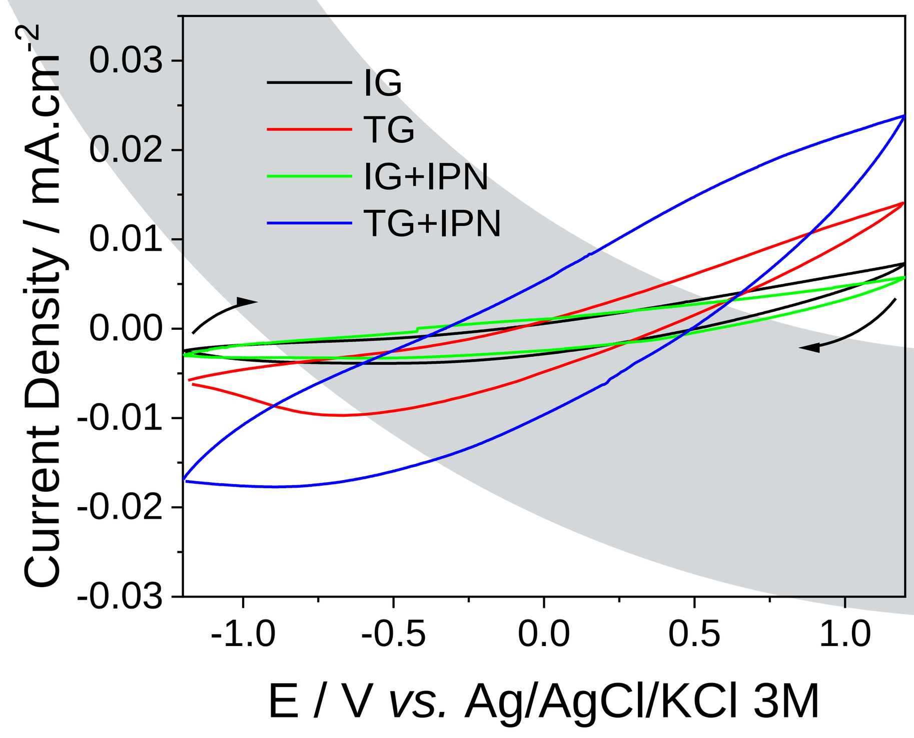

Fig. 9 Cyclic voltammetry of 4 kinds hydrogel.

	TG	TG+IPN	IG	IG+IPN
R_s ($\Omega\ cm^2$)	2.78	2.11	2.25	1.96
R_{PEDOT} ($\Omega\ cm^2$)	1.36	0.66	16.44	54.50
σ_{PEDOT} ($mS\ cm^{-1}$)	155.4	323.6	11.7	3.5

Fig. 10 Results table.

Conclusions

Interpenetrating Network increase the conductivity of TG significantly.

Electrical conductivity:

TG+IPN > TG > IG/IG+IPN

References

[1] Yuk, H., Lu, B. and Zhao, X., 2019. Hydrogel bioelectronics. Chemical Society Reviews, 48(6), pp.1642-1667.

Acknowledgements

Special thanks to Dr. Arua Da Silva for his supervision and assistance during the project.

Thanks to the Insigneo Institute for funding this project.

The Insigneo Institute for *in silico* Medicine is a collaborative initiative between the University of Sheffield, Sheffield Teaching Hospitals NHS Foundation Trust and Sheffield Children's Hospital.

The University Of Sheffield.

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