Electro-Assembled Hydrogels for Wireless Drug Loading

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Background

With the growing interest in precise and controlled drug release in the medical field, the search for innovative drug delivery systems has become one of the current research priorities.
The development of bipolar electrochemical methods offers a potential solution [1]. A potential difference is applied to a conductive polymer material conductor. When a conductive polymer material (hydrogel) is inserted into an electrolyte solution so that it is in an electric field formed by two driving electrodes, one end of the material is positively polarised and the other end is negatively polarised (as shown in Figure 1). This polarisation causes oxidation and reduction reactions at both ends of the electrodes.
The main idea of this project is whether the drug being added to the electrolyte solution can be added to the conductive hydrogel in the presence of an electric field.

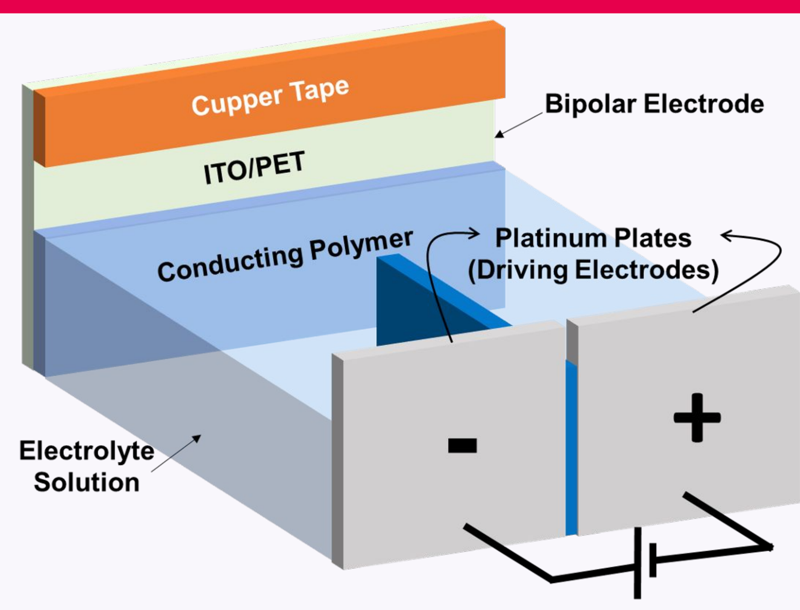

Fig.1 Demonstration of the bipolar electrochemical experimental setup in this project

Methods

Fig.2 A voltage of 2 V was stably supplied for 120 s in the as-figured device and the PEDOT/Alginate hydrogel was successfully deposited on ITO working electrode.

The deposition of PEDOT/Alginate hydrogels will be performed using the chronoamperometry technique, where a constant voltage is applied to the pre-processed ITO film [2] (demonstrated in Fig.2). Fig.3 shows the actual setup for the bipolar experiment in the next step.

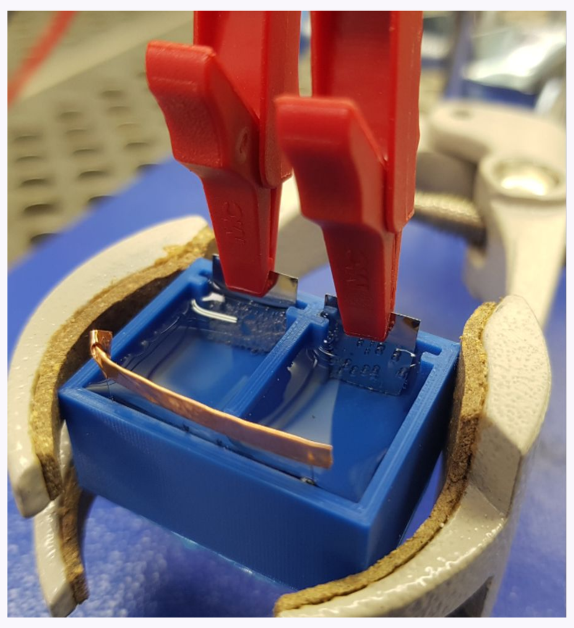

Fig.3 Actual picture of the 3D-printed device used to realise the bipolar experiment. The prepared hydrogels and the drug to be loaded will be added to the contained solution. The device is connected to a potentiostat.

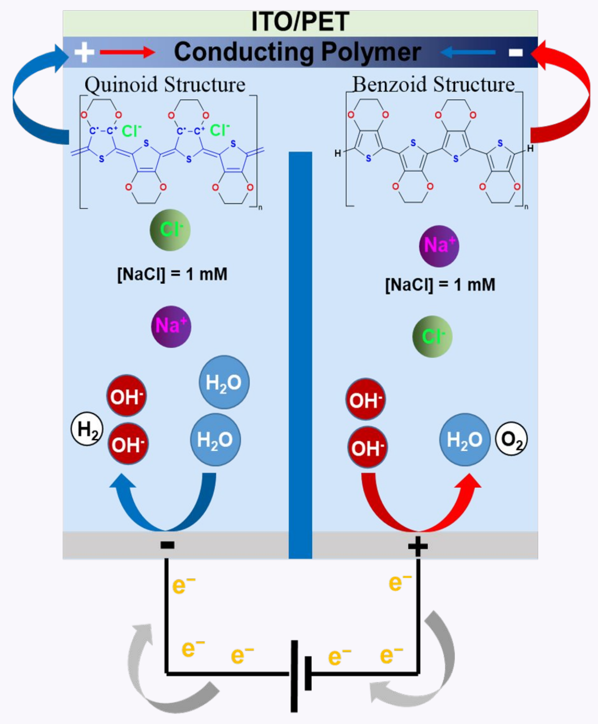

Fig.4 Electrochemical Reaction of the Conductive Hydrogel in the Bipolar Experiments.

Bipolar experiment will continuously apply 2mA current for 300 sec to the hydrogel (chronopotentiometry). The reactions in the device are visualised in Fig.4 for explanation. Surprisingly, the oxidised and reduced sides of the hydrogel will be obtained different appearances as in the Fig.5.

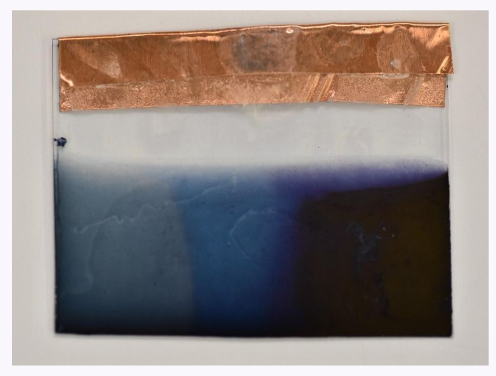

Fig.5 Differential appearance of conductive hydrogels from oxidised and reduced electrodes after bipolar experiment (Light and Dark)

Demonstration video of the experiment can be viewed from QR Code:

Results

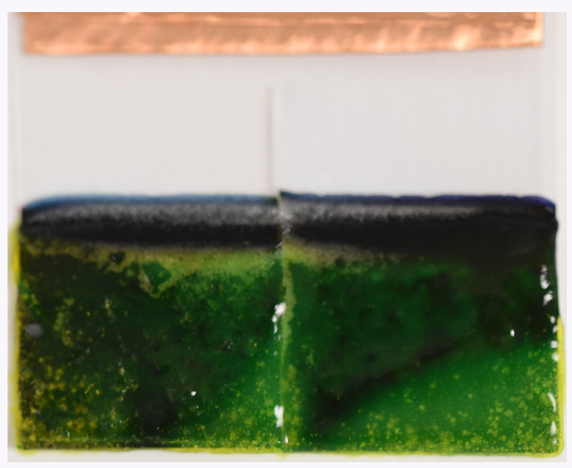

Fig.6 Bipolar electrochemical loading of drug successful sample (where the drug was replaced with fluorescein in this experiment).

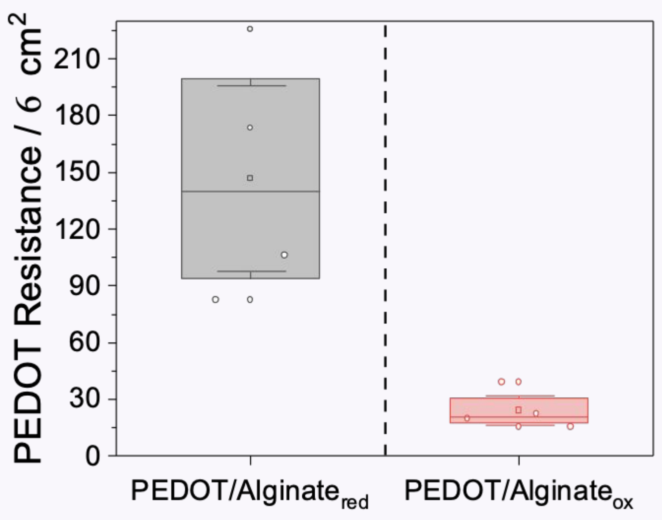

Fig.7 Comparison of resistance of two different electrode ends in hydrogels.

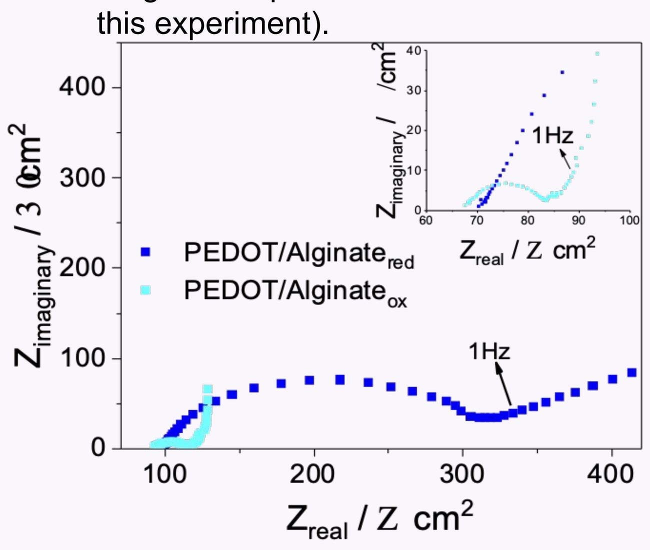

Fig.8 Comparison of Electrochemical Impedance Spectroscopy (EIS) results of two different electrode ends in the hydrogel.

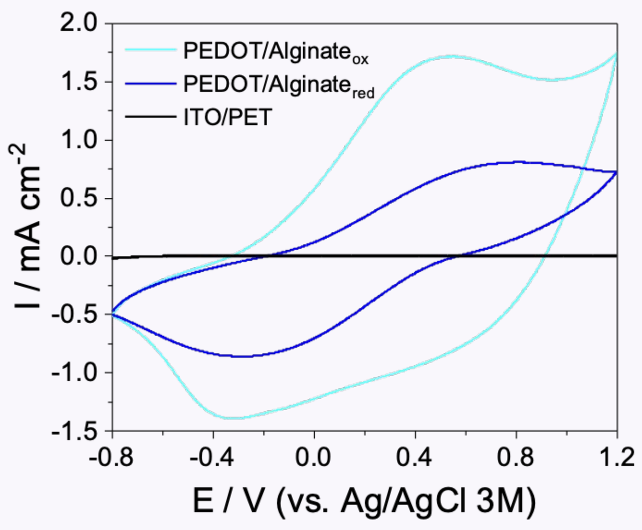

Fig.9 Comparison of Cyclic Voltammetry (CV) results of two different electrode ends in the hydrogel.

The drug was successfully wirelessly loaded onto the conducting hydrogel as shown in Fig.6. While the oxidised and reduced sides were characterised and compared, the oxidised side (Light side) possessed significantly better conductivity (demonstrated in Fig.7-9).
Passive and electrically activated release of drugs was also used to evaluate the potential of PEDOT/Alginate hydrogels for drug delivery. According to Figures 10-12, this hydrogel enables wireless loading of drugs and the oxidised side has a relatively better performance.

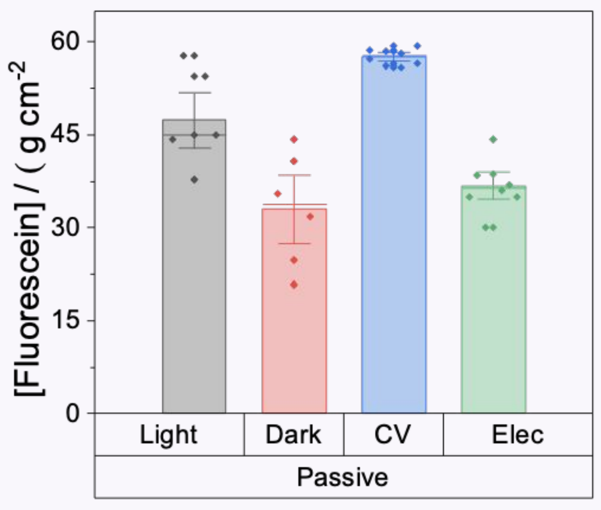

Fig.10 Passive drug release results of the samples

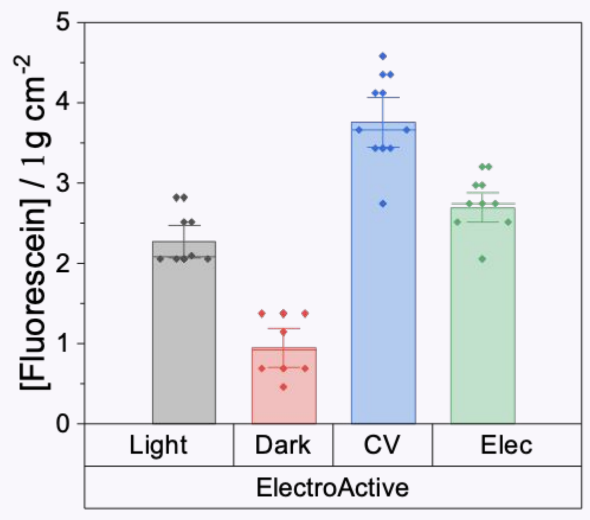

Fig.11 Electric active drug release results of the samples

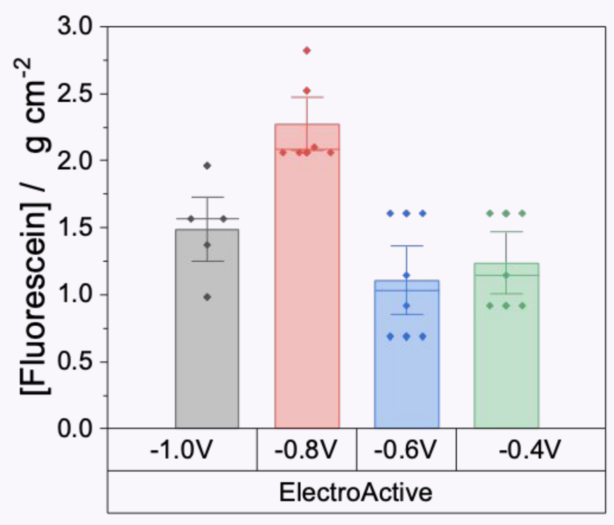

Fig.12 Results obtained by applying different voltages to the oxidised side for electric activated drug releasing. -0.8V obviously has the best result that means the hydrogel was delivered and saved the most drugs

Conclusions

Bipolar electrochemistry offers a new solution for wireless drug loading of hydrogels. The side of the hydrogel that is oxidised (Light side) exhibits far better electrochemical characteristics than the other side.

Besides, based on the PEDOT/Alginate hydrogel involved in the project, applying -0.8V gives the best drug loading and releasing data.

References

[1] Crooks, Richard M. Principles of bipolar electrochemistry. ChemElectroChem, 2016; 3(3): pp.357-359.
[2] Da Silva, AC, Paterson, TE, Minev, IR. Electro-assisted assembly of conductive polymer and soft hydrogel into core-shell hybrids. Soft Science. 2023; 3(1): 3. http://dx.doi.org/10.20517/ss.2022.25

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