pH and electro-responsive hydrogels with adhesive and sensing properties for tissue regeneration

Cofinançat per la Unió Europea

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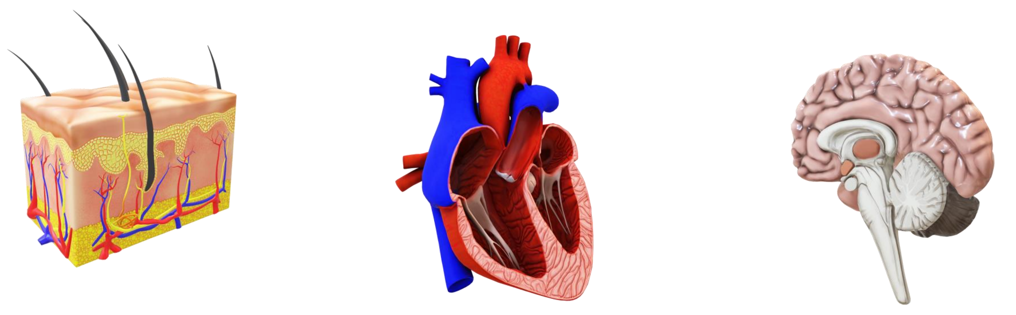
INTRODUCTION

Multifunctional hydrogels represent one of the dominants soft material in Biomedical Engineering. The design of multi-component hydrogels can allow the development of new devices which combine advanced features, making them ideal platforms to **promote tissue growth** and regeneration.

Hydrogel scaffolds capable of **responding to pH** may be employed for controlled drug release, in order to get rid of pathogens during tissue regeneration, while **conductive polymer** and hydrogel matrices that can be stimulated electrically are beneficial for the **regeneration** of those **tissues** that are **sensitive to electrical signal**: cardiac, skin and nerve tissue.

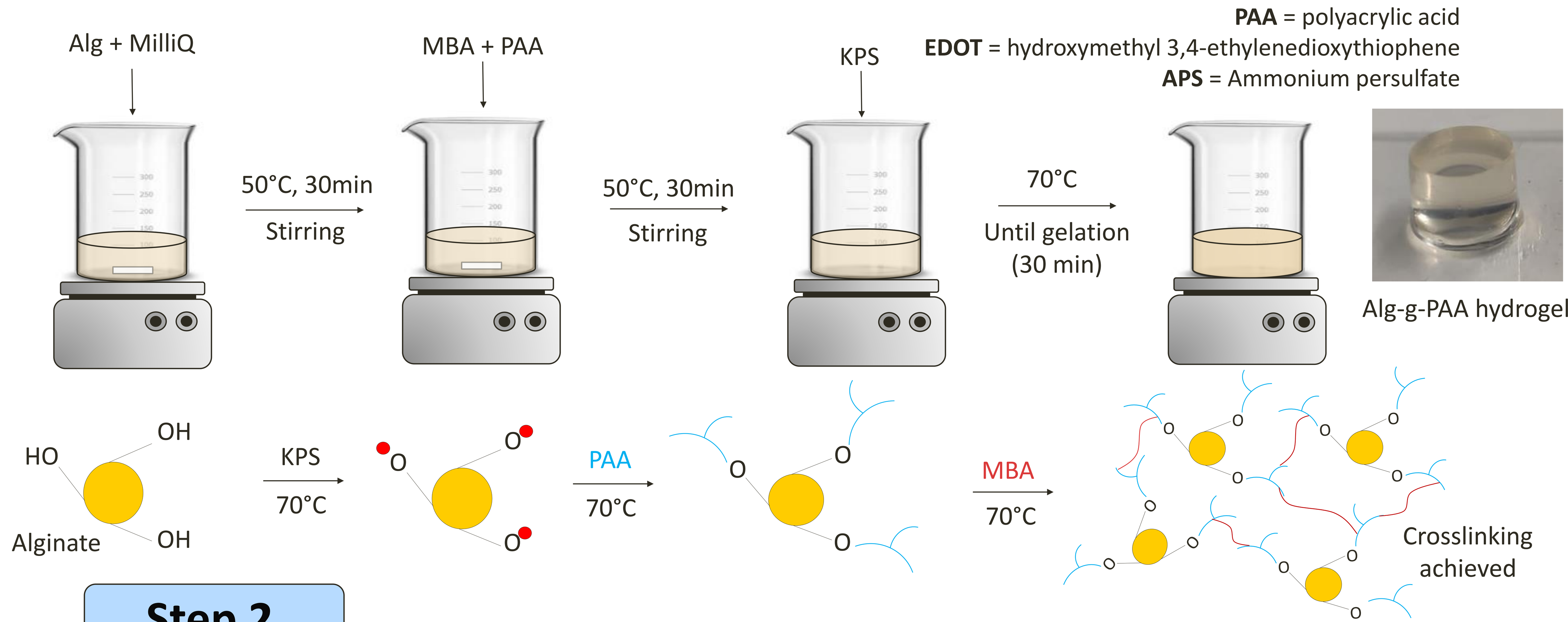


Skin tissue — Cardiac muscle tissue — Nerve tissue

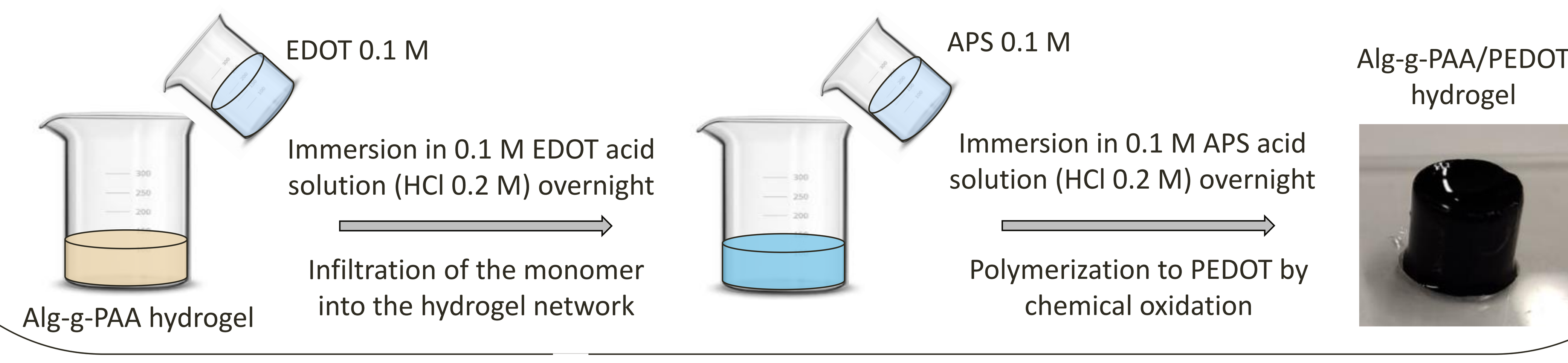
SYNTHESIS

Alg = alginate
KPS = potassium persulfate
MBA = N,N′-Methylenebisacrylamide
PAA = polyacrylic acid
EDOT = hydroxymethyl 3,4-ethylenedioxythiophene
APS = Ammonium persulfate

Step 1

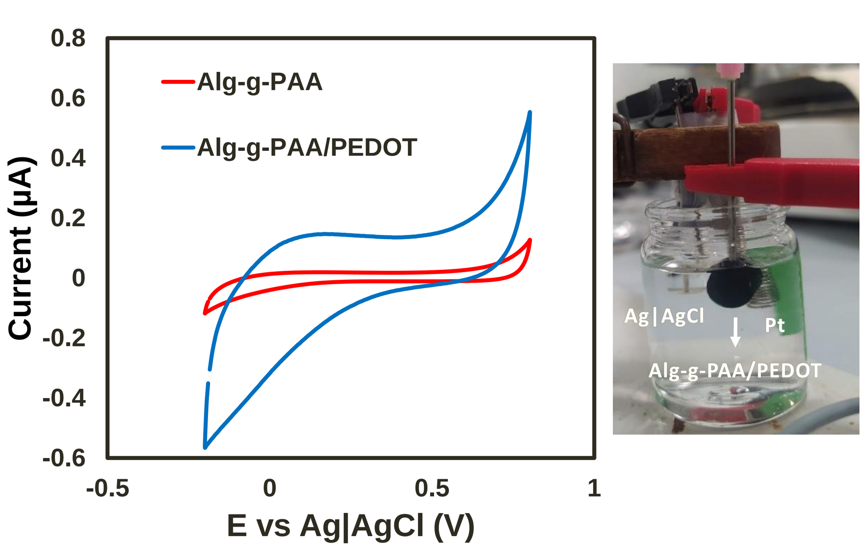


Step 2



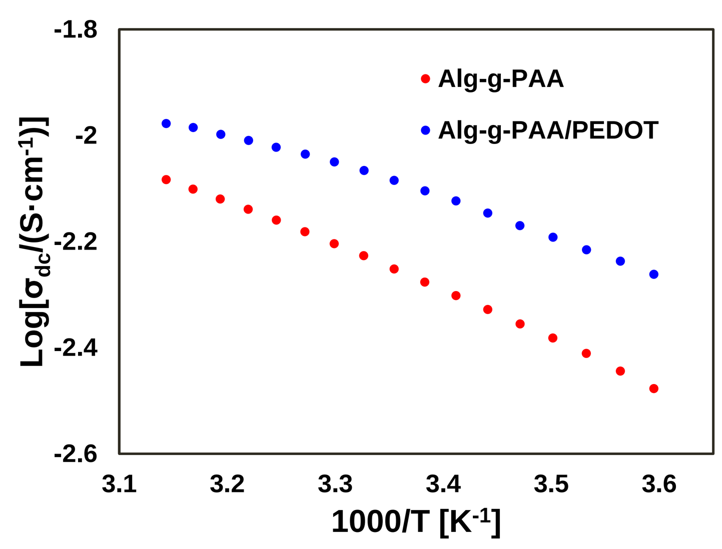
CHARACTERIZATION

Cyclic voltammetry



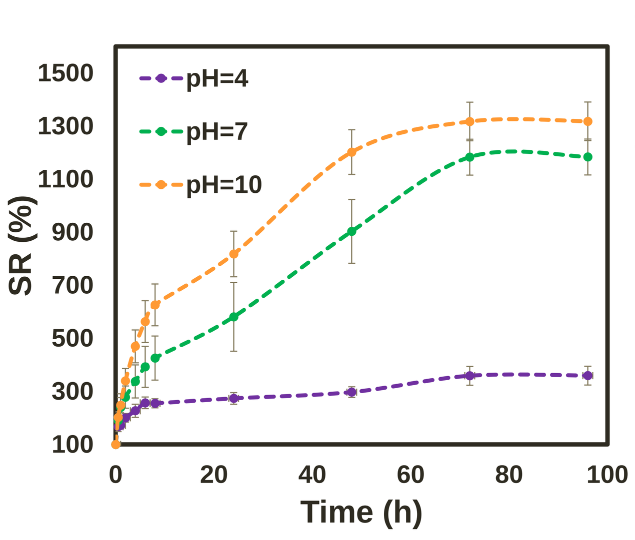
Set-up used for electrochemical measures (right) and cyclic voltammograms recorded for hydrogels (left).

Dielectric response



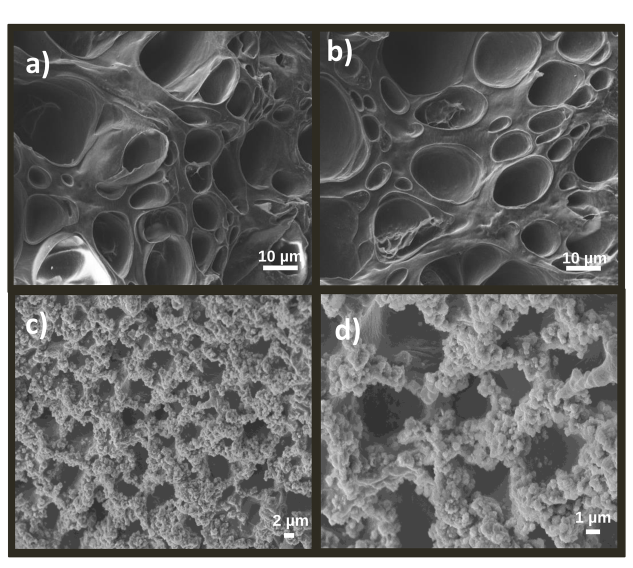
Arrhenius plot of the dc conductivity of Alg-g-PAA and Alg-g-PAA/PEDOT hydrogels.

Swelling ratio (%)



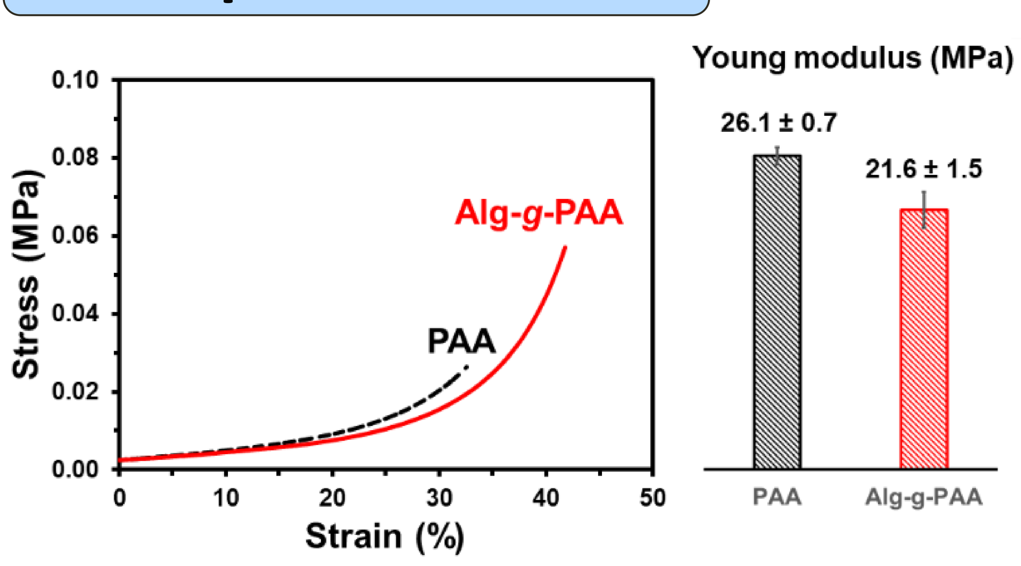
Temporal evolution of the SR (n=3) after immersion of hydrogel in PBS solution at 37 °C and different pH.

SEM



Cross section SEM micrographs of Alg-g-PAA (a-b) and Alg-g-PAA/PEDOT (c-d) lyophilized hydrogels.

Compression test

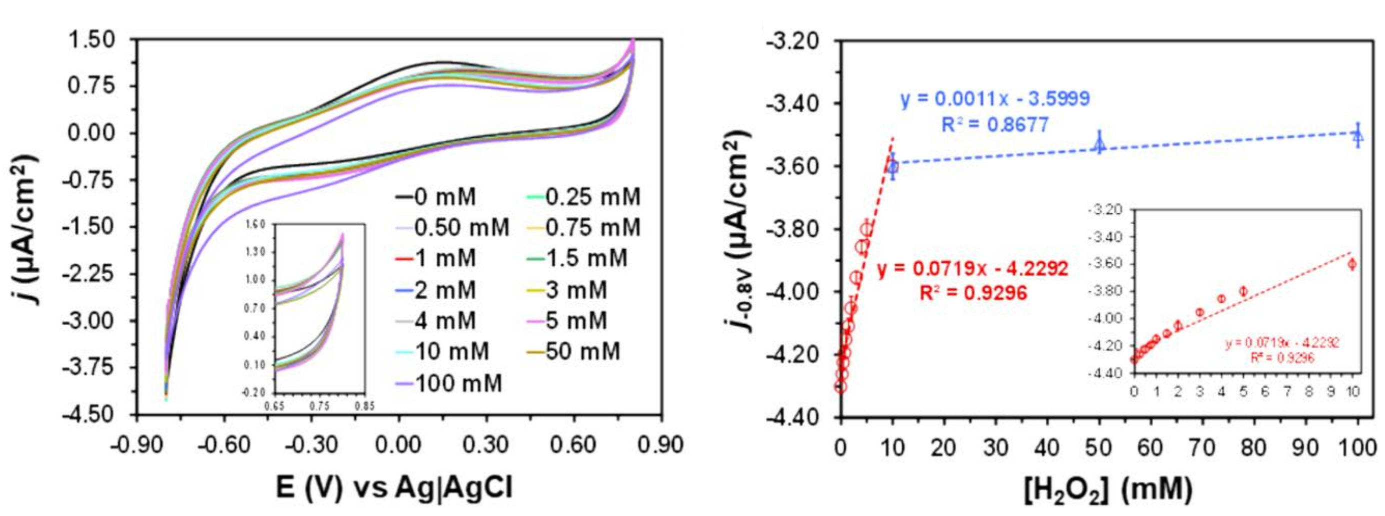


Representative compression curves obtained for Alg-*g*-PAA and PAA hydrogels (left) and comparison of the Young modulus (right).

Scan me!

APPLICATIONS

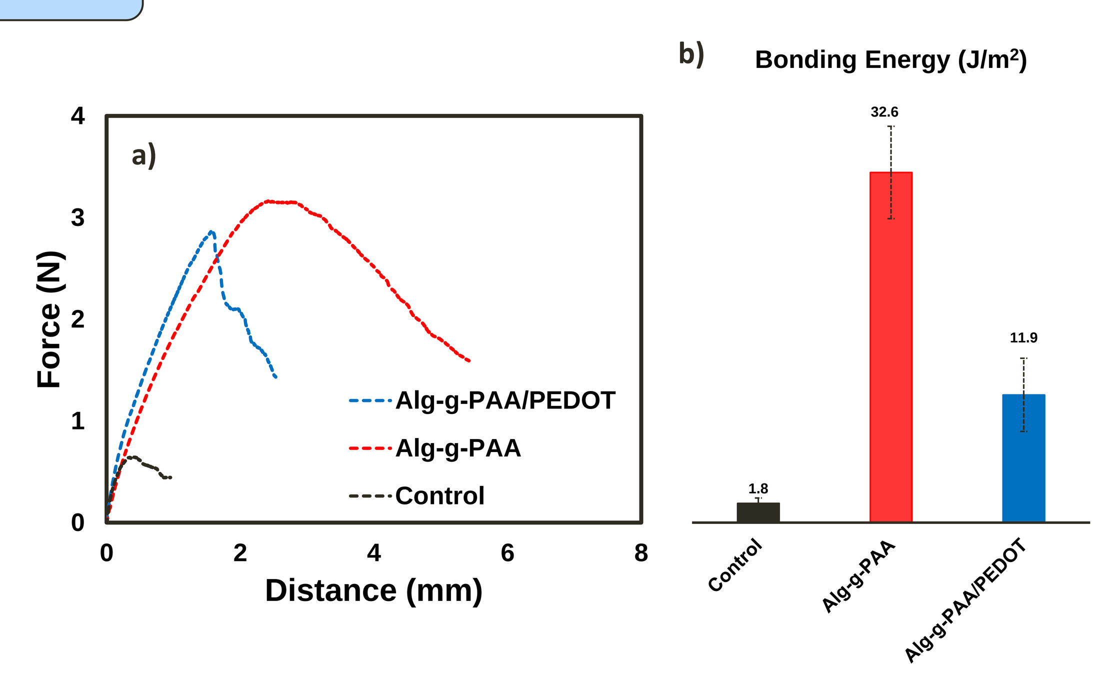
H_2O_2 sensor

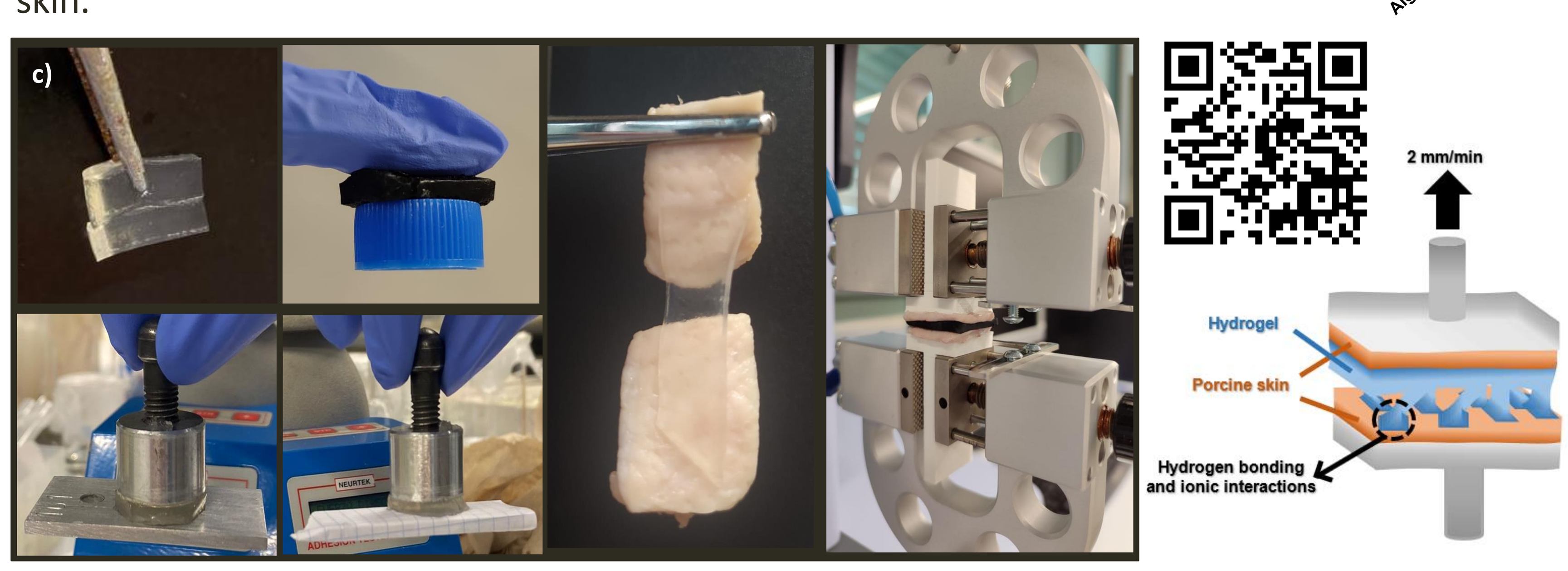


H_2O_2 detection: Cyclic voltammograms and calibration profile for Alg-g-PAA/PEDOT hydrogel.

Biomedical adhesive

(a) Representative force-distance curves obtained for Alg-g-PAA, Alg-g-PAA/PEDOT hydrogels and control systems; and (b) bar plots of the corresponding bonding energies (n = 6). (c) Digital photograph of both hydrogels sticking to different surfaces: rubber, paper, steel and porcine skin.





CONCLUSIONS

1) The **electrochemical activity** of Alg-g-PAA is enhanced by loading electroactive PEDOT.
2) The hydrogel is **pH responsive** due to the ionic repulsion between carboxylate groups, which affects the swelling behavior, thus controlling water penetration.
3) The polymer (PEDOT) was distributed homogeneously throughout the porous surface of the hydrogel, as shown in SEM images.
4) The Young modulus obtained for Alg-g-PAA (21.6 ± 1.5 MPa) is within the range of values determined for human skin (from 5 kPa to 140 MPa), which is a highly anisotropic and **viscoelastic** tissue.
5) The potential application of the conducting hydrogel as **biosensor** for the electrochemical detection of hydrogen peroxide was explored. Alg-g-PAA/PEDOT, exhibited a sensitivity to the presence of H_2O_2 of 71.9 mA/(cm²·mM) and a detection limit of 0.9 mM.
6) The capacity of Alg-g-PAA and Alg-g-PAA/PEDOT to bond fractured tissues was assessed using porcine skin. The results are remarkable merits to consider that this hydrogel is a promising candidate to be used as an **adhesive** in **biomedical field**, prospecting its potential in skin tissue regeneration.

References

- Ramírez-Alba, M. D., Molins-Martínez, M., García-Torres, J., Romanini, M., Macovez, R., Pérez-Madrigal, M. M., & Alemán, C. (2024). pH and electrically responsive hydrogels with adhesive property. *Reactive and Functional Polymers*, *196*, 105841.
- Ramírez-Alba, M. D., Álvarez-Caballero, A., Resina, L., Romanini, M., Macovez, R., Pérez-Madrigal, M. M., & Alemán, C. (2024). Alginate-graft-polyacrylic acid electro-responsive hydrogels: Impact of the conducting polymer and application as hydrogen peroxide sensor. *European Polymer Journal*, *219*, 113388.