Iontronic Hydrogels for Multipurpose Bio-Interfaces

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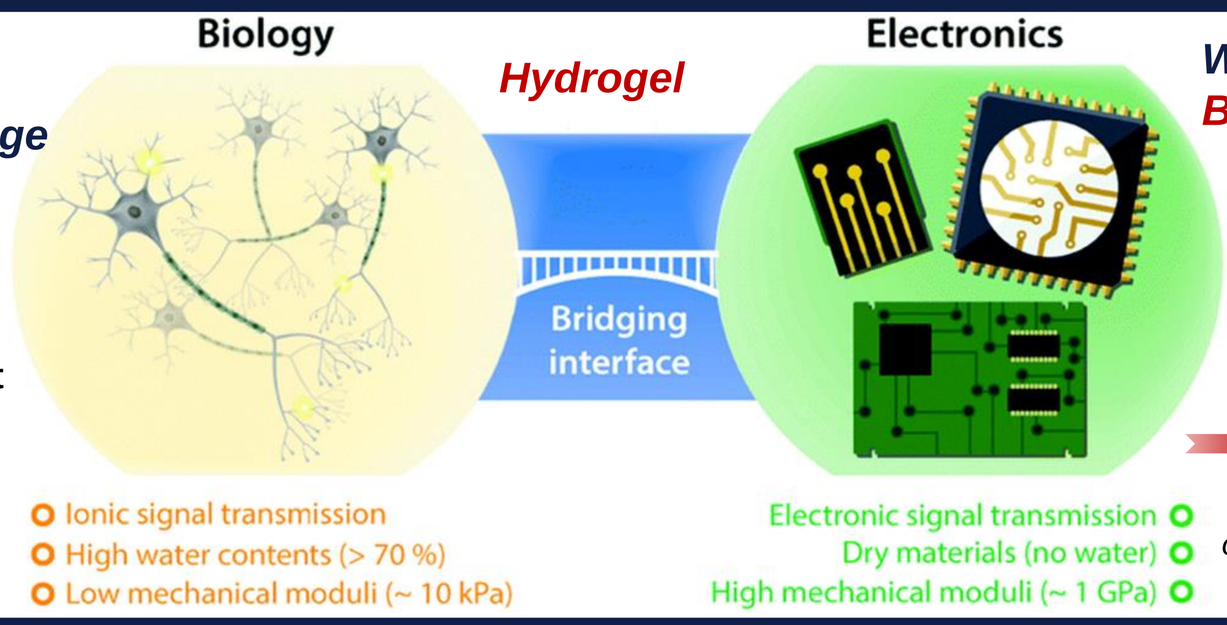
1. Introduction

Iontronics, speaking the language of biology

Human tissues communicate via **ionic fluxes**,

Electronics through **electron transport**

→ Iontronics bridge between these two carriers.



What defines an effective Bio-Interface ?

→ enable **ionic–electronic transduction**
→ matching the **soft, hydrated, dynamic** nature of living tissues.

→ ***Hydrogel***
- **water-rich,**
- **ion-conductive,**
- **tissue-like mechanics**

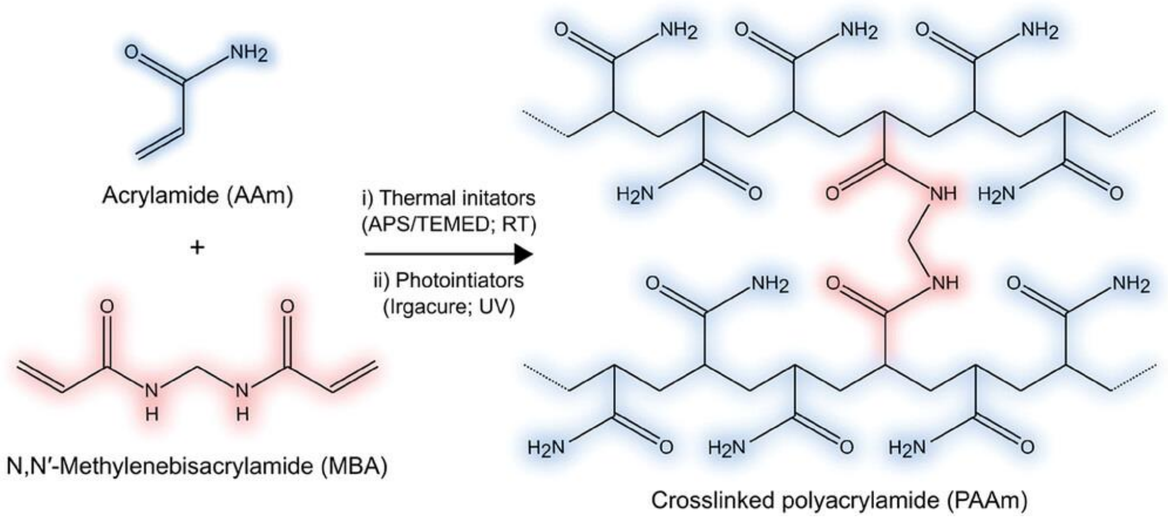
*offer **biocompatible** and **tunable scaffolds** for bio-electronic integration.*

Chem. Soc. Rev. **2019**, 48, 1642-1667

2. Fabrication Mechanisms :

Method 1

Free-radical polymerization (UV / Thermal) → Covalently cross-linked PAAm hydrogel



Milos, F. et Del Campo, A. (2024) « Polyacrylamide hydrogels as versatile biomimetic platforms to study cell-materials interactions », Advanced Materials Interfaces, 11(34), p. 2400404. Disponible sur: https://doi.org/10.1002/admi.202400404.

Method 2

Physically Crosslinked PVA Hydrogels (Freeze–Thaw Mechanism)

i. ***Freezing*** → ice crystals form, water expelled, PVA chains align

ii. ***Thawing*** → hydrogen-bonded crystallites remain as physical crosslinks

iii. ***Repetition*** → *increases crystallinity*

→ stronger tunable *yielding a reversible, tunable network with tissue-like mechanics*

3.1. Wearable Hydrogel

How can Hydrogels be tuned ?

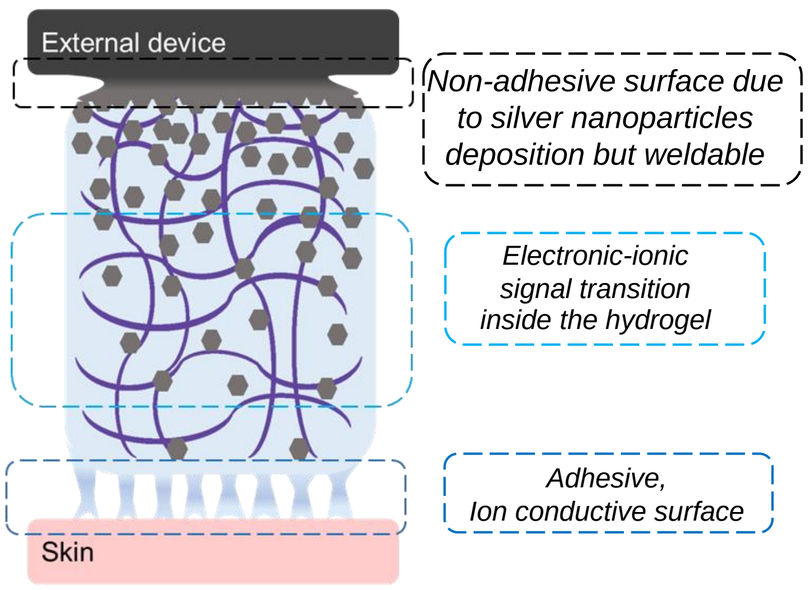
By varying MBAA (crosslinker), NaCl, & tannic acid
→ influence **softness**, **conductivity**, and **adhesion**

How is adhesion ensured ?

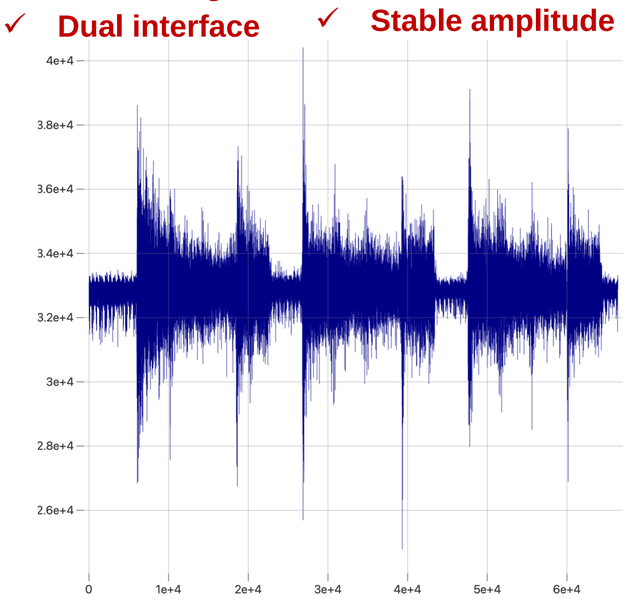
Tannic acid → H-bonding & π–π interactions with tissue, providing stable and conformal attachment

How is ionic conductivity induced ?

NaCl → mobile ions for signal transduction



✓ **Cleaner signal** ✓ **Noise control**
✓ **Dual interface** ✓ **Stable amplitude**

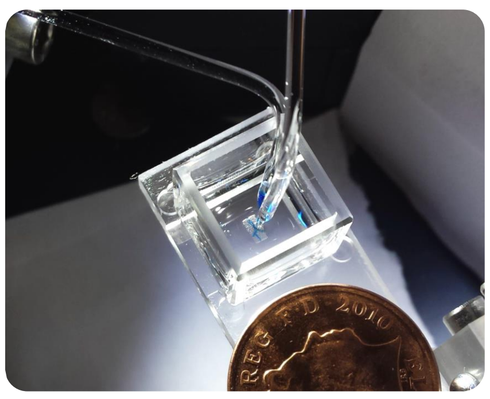


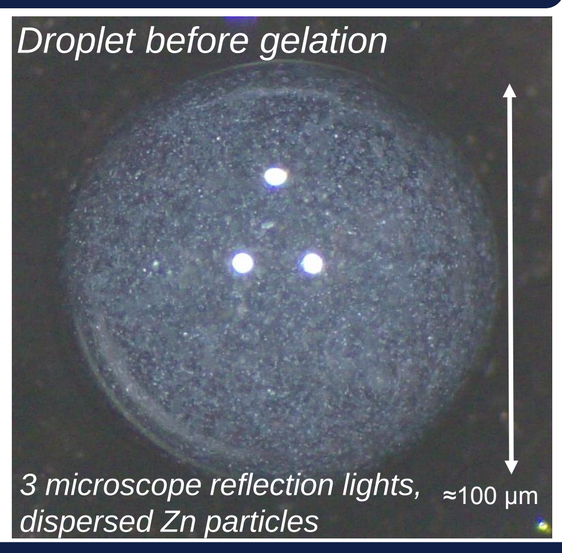
EMG recording with hydrogel interface

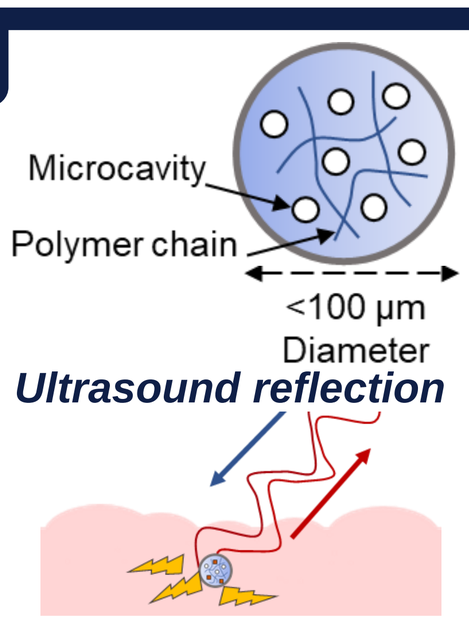
Reliable signal recording and durable device integration

3.2 Implantable droplet

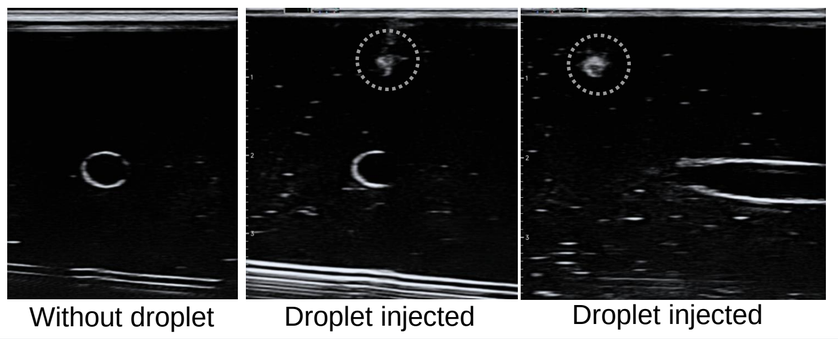
Droplet printing







How are hydrogel droplets fabricated?
Droplet printing + gelation; ZnO removal → *cavities*; agarose → *biodegradability*
Why cavities?
reduce *acoustic impedance mismatch*, improving tissue transmission
What for? As implantable ultrasound contrast agents, droplets enhance scattering and imaging



Without droplet | Droplet injected | Droplet injected

4. Outlook

Next Steps:

- Micro-CT for 3D droplet cavity mapping.
- Extend to ECG/EEG applications
- Wire bonding validation on asymmetric hydrogel.

Impact:

- **Dropletronic biointerfaces → autonomous ionic biomedical devices**
- **Soft hydrogels** open **new horizons for tissue engineering and biosensing**
- **1st assymetric solderable hydrogel**.
- **Adaptive, human-centered biointerfaces** as a foundation for future diagnostics and therapies