Institute of Electronic Materials and Devices

Leibniz Universität Hannover

Hydrogel-Gold-Nanoparticle Composites - Initial Investigation of Electrical Behavior using Electrochemical Impedance Spectroscopy

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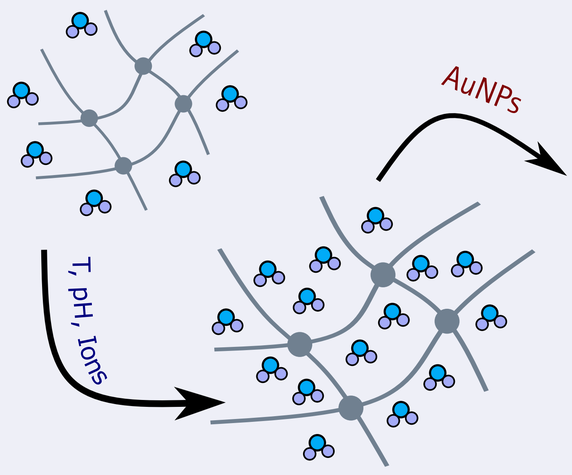
Motivation & Background

Smart Hydrogels:

- 3D cross-linked polymer networks responsive to external stimuli via reversible volume change [1]
- Modifiable via integration of nanoparticles [2]
- Biocompatibility makes them suitable candidates for biomedical applications [3]

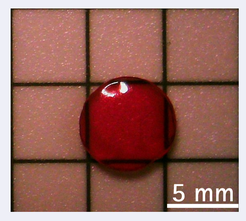
Research Goal:

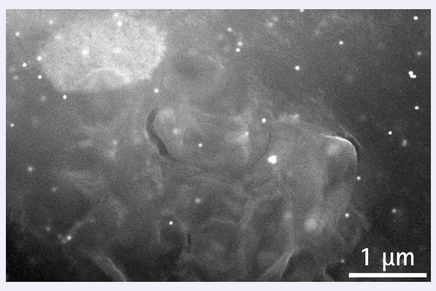
- Assessment of potential for biomedical sensing requires understanding of electrical behavior, i.e. impedance



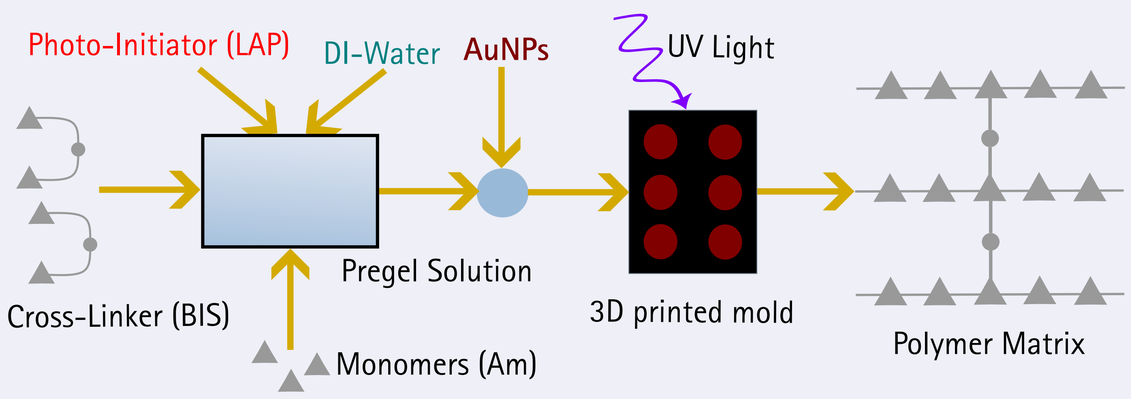
Composites of Interest:

- Polyacrylamide (PAM) discs of 5 mm diameter as base matrix
- Integrated gold nanoparticles (AuNPs) with different diameter (50 nm; 15 nm) and concentration (1x; 8x - volume referenced)
- AuNPs with polyvinylpyrrolidone (PVP) surface termination
- Storage solution: 1x phosphate buffered saline (PBS)



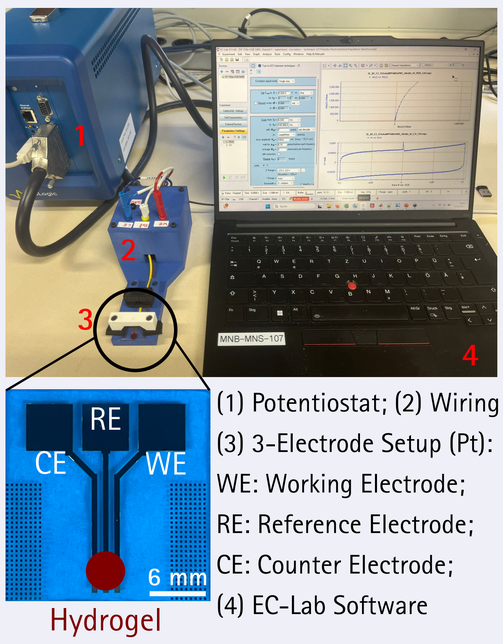


Sample Fabrication

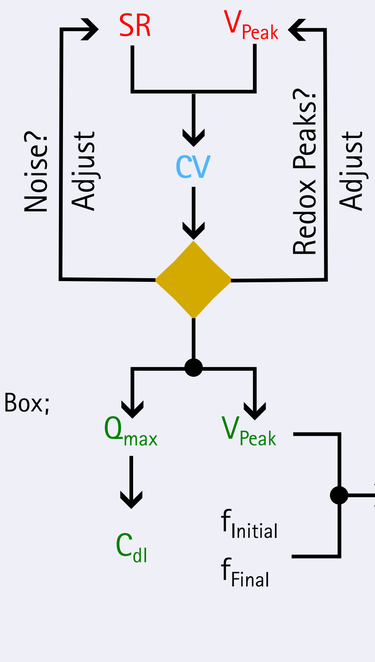


- Acrylamide (Am) monomers require acrylamide-based cross-linker (BIS)
- LAP photo-initiator activation via UV light leads to double bond breakage to enable polymer chain formation and propagation
- Necessary UV exposure time dependent on AuNP concentration (1 min for 1x; 8 min for 8x)
- Post-fabrication washing in deionized water for 3 days prior to storage in 1xPBS (24h)

Experimental Procedure



(1) Potentiostat; (2) Wiring Box; (3) 3-Electrode Setup (Pt): WE: Working Electrode; RE: Reference Electrode; CE: Counter Electrode; (4) EC-Lab Software

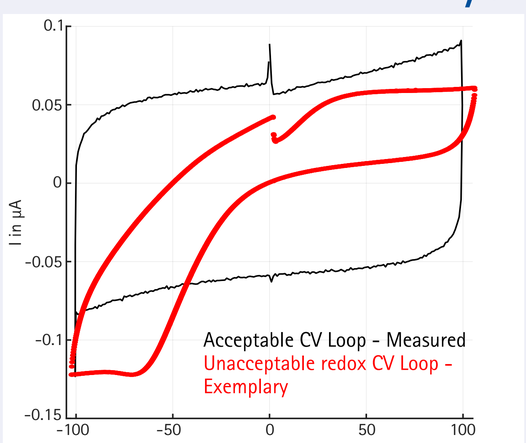


- Maximum charge as indication of double layer capacitance (C_{dl}) using cyclic voltammetry (CV)
- Electrochemical Impedance Spectroscopy (EIS) to invesitgate impedance Z as a function of AuNP diameter and concentration

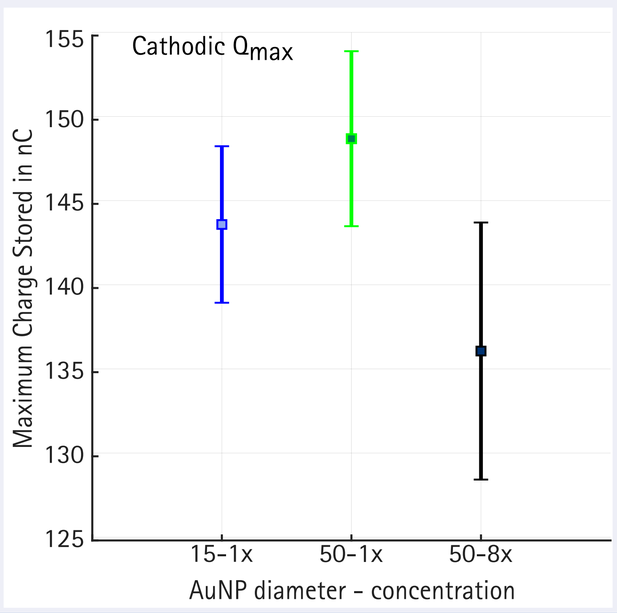
SR: scan rate
V_{peak}: peak voltage
Q_{max}: maximum charge
f: frequency

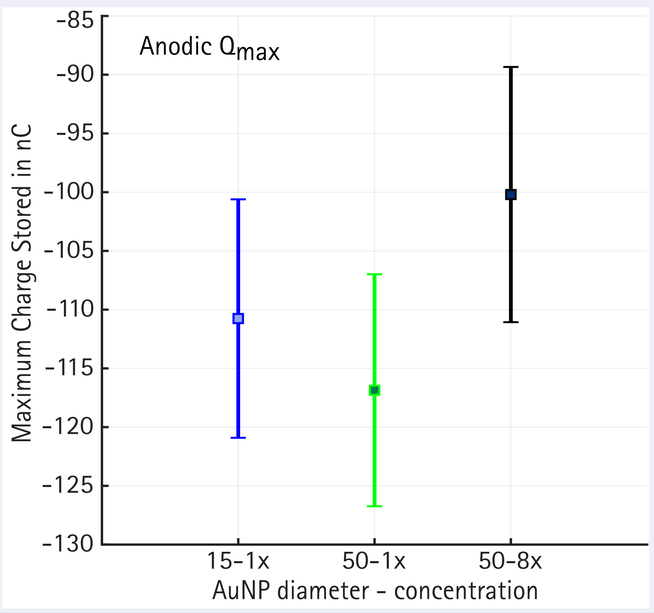
Results

Cyclic Voltammetry

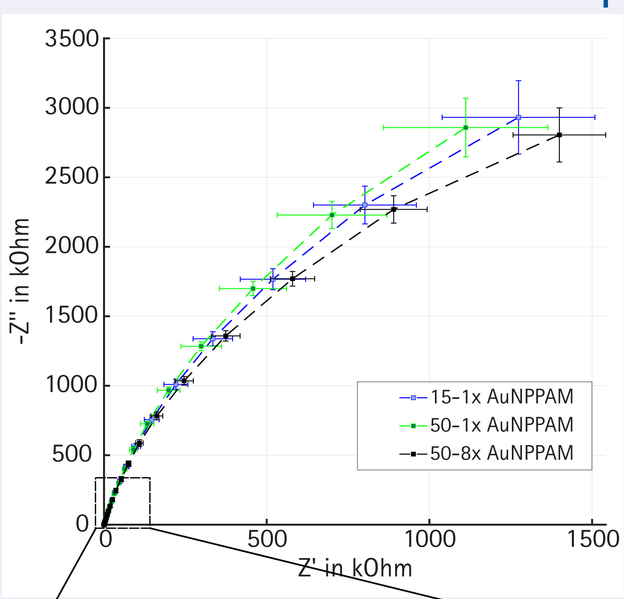


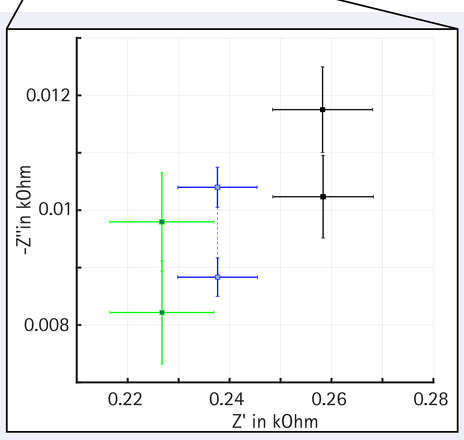
- CV with SR of 50 mV/s and V_{peak} of ± 100 mV delivers an E-I loop free of redox reaction peaks
- Only inherent AuNP-PAM properties are investigated
- Accumulated Q_{max} calculated from measured current (cathodic: bottom left; anodic: bottom right) -> First indication of C_{dl}
- Number of AuNPs: 15-1x > 50-8x > 50-1x
- $Q_{max,50\text{-}1x} > Q_{max,15\text{-}1x} > Q_{max,50\text{-}8x}$





Electrochemical Impedance Spectroscopy





Frequency	$Z_{50\text{-}1x}$ in kOhm	$Z_{15\text{-}1x}$ in kOhm	$Z_{50\text{-}8x}$ in kOhm
0.057 Hz	1762.8 ± 41.66	1843.7 ± 68.50	1863.6 ± 42.15
39.5 Hz	4.506 ± 0.18	4.70 ± 0.22	5.05 ± 0.35
100 kHz	0.23 ± 0.01	0.24 ± 0.007	0.26 ± 0.009

- Non-faradaic EIS measurements depict electrode-electrolyte interface [4,5]
- Initial values for real component Z': Electrolyte resistance R_s (50-8x > 15-1x > 50-1x) [5]
- Semicircle width along Z': Charge transfer resistance R_{ct} (50-8x > 15-1x > 50-1x) [5]
- General trend observed: $Z_{50\text{-}8x} > Z_{15\text{-}1x} > Z_{50\text{-}1x}$

Conclusions

- Electrochemical analyis suitable for investigation of impedance character of hydrogel composites
- Increasing number of AuNPs hinders charge motion through composite which increases impedance
- Further investigation of AuNP diameter-concentration interplay necessary

References

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