

## Synthesis and Optimization of Alginate-Polypyrrole Composites for Neural Implants

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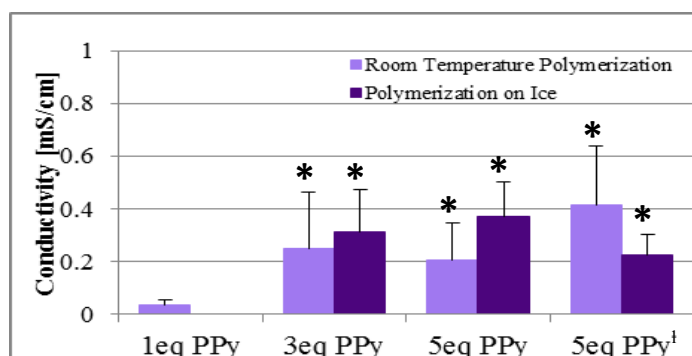
**Statement of Purpose:** Alginic acid and its salts (alginates) are linear carbohydrate co-polymers that are typically extracted from seaweed. The material is a block copolymer of  $\beta$ -D-mannuronate (M) and  $\alpha$ -L-guluronate (G), with the latter residue playing an important role in the presence of certain metal ions having a charge of two or greater.  $\text{Ca}^{2+}$ , for example, acts as an efficient cross-linker, which results in a gel with variable viscoelasticity. The rigidity of the material is largely a function of the ion density and distribution in the host polymer. We are interested in composites of alginates with polycationic intrinsically conducting polymers (ICPs), particularly polypyrrole (PPy) and poly(3,4-ethylenedioxythiophene) (PEDOT) as scaffolds for neural tissue growth and regeneration.

**Methods:** Sodium alginate (ALG) dissolved in 50mL of deionized water to a concentration of 2% (w/v) was used as the base for these constructs. Pyrrole and potassium persulfate (KPS) were added and stirred at room temperature for 24h to allow the polymerization of polypyrrole (PPy). This was followed by 48h of dialysis for purification. Buffers, chelation agents (EDTA), and bases were added for optimization of the polymerization reaction conditions to protect the alginate from oxidation; these included EDTA, pyridine, phosphate buffers, PIPES, and sodium bicarbonate. Additional variables investigated included concentration of pyrrole and reaction temperature. Resultant materials were analyzed using IR with an ATR attachment, rheometer for viscosity, quartz crystal microbalance (QCM; viscoelasticity), 4-point probe for conductivity, and a pH meter.

**Results:** Polypyrrole is formed by the oxidative polymerization of pyrrole, giving an electronically conducting polycation.<sup>1</sup> During the polymerization reaction, two protons are generated per monomer. This results in decreased solution viscosity as well as fragile hydrogels on crosslinking and poor, powdery cast films. Further, IR spectroscopy shows the presence of a carbonyl peak (ca.  $1725\text{ cm}^{-1}$ ), consistent with the oxidative degradation of alginate. Addition of EDTA had little effect on material properties. Inclusion of base (pyridine, sodium bicarbonate) or PIPES greatly reduced or eliminated the growth of the carbonyl peak. Solution viscosity was maintained and robust, flexible films were formed upon drying. Neither the addition of chelators or bases altered viscosity, however increasing the polypyrrole content did have a significant impact on the viscosity of ALG-PPy solutions ( $p=0.02$  and  $0.03$  for 2eq and 5eq PPy, respectively). Additionally, it was found that 8h polymerization endpoint with use of excess sodium bicarbonate produced the best results for all properties tested.

**Table 1:** Overview of results of optimization variables

Table 1: Variable Optimization	Function	Film Formation	Inhibit Carbonyl Peak	pH	Viscosity	Conductivity
ALG + PPy + KPS	Control	—	—	—	—	—
+ EDTA	Metal Chelator	—	—	—	✗	—
+ Pyridine	Base	✓	✓	✓	✗	✓
+ Sodium Bicarbonate	Base	✓	✓	✓	—	—
+ Phosphate buffer	Buffer	✓	✓	—	—	✓
+ PBS	Buffer	—	—	—	✗	—
+ PIPES	Buffer	✓	✓	✓	—	✓
ALG + 2 eq. PPy + KPS + Sodium Bicarbonate	↑PPy, Base	✓	✓	✓	✓	✓
ALG + 5 eq. PPy + KPS + Sodium Bicarbonate	↑PPy, Base	✓	✓	✓	✓	✓



**Figure 1:** Conductivity optimization for polymerization temperature with increasing polypyrrole content; <sup>†</sup> indicates DI water at pH 7.4. (\* indicates material is significantly higher compared to 1eq PPy ( $p < 0.05$ ))

**Conclusions:** Control of pH is key for protecting alginate from oxidation during the polymerization of pyrrole. By controlling the reaction environment, higher quality constructs (increased conductivity and hydrogel formation) can be formed. Additionally, it is paramount to control the pH in order to increase cell viability on the resultant hydrogels. Further investigation into increasing conductivity and conditions for optimal cell growth are underway.

### References:

<sup>1</sup> Electrically conducting polymers: a review of the electropolymerization reaction Waltman, R. J.; J. Bargon. Can. J. Chem. 1986, 64, 76-95.

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