Hydrogel Composites Containing Carbon Nanobrushes as an Effective Biomaterial for Tissue Regeneration

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Statement of Purpose: Hydrogels provide three-dimensional encapsulating scaffolds similar to the environment found in vivo in which cells can maintain normal functioning and exhibit tissue growth while being easily examined [1]. Pluronic F-127 poloxamer is a thermoreversible triblock copolymer mixture of polyethylene oxide and polypropylene oxide (PEO_{101}-PPO_{56}-PEO_{101}) that is hydrophilic and non-ionic. This study aims to examine the rheological suitability of a hydrogel scaffold as an effective biomaterial for tissue growth using pluronic F-127 poloxamer with electrically conductive carbon nanobrushes (CNB) embedded within the hydrogel.

Methods: The 30wt% poloxamer solution (Sigma, USA) and the CNB were produced according to established procedures [2]. The gels were produced in a 4°C fridge before being incubated at 37°C to solidify the gels once they had been poured and the CNB uniformly distributed within the hydrogel composites. Gels were produced with 0vol% CNB, 0.1vol% CNB, 0.5vol% CNB, 1vol% CNB and 5vol% CNB and stored in an incubator at 37°C. This allowed the gels to be stored during testing without liquefying at room temperature due the thermoreversible nature of the poloxamer hydrogels. These gels were tested on a TA AR-G2 Rheometer with 20mm steel plate with controlled temperatures. Time sweeps were performed at 37°C. Frequency sweeps were performed at an angular frequency of 0.01-5 rad/s at 37°C.

Results: Frequency sweep studies performed at 37°C showed a crossover from a regime dominated by elastic effects to one dominated by viscous effects at an angular frequency around 0.03rad/s for the hydrogels regardless of CNB content. Increased CNB content led to the regime change at a higher frequency, but the difference was negligible. Regardless of CNB content, the hydrogels still had a large G" component at the crossover point, indicating that while viscoelastic effects become dominant, they are still quite elastic in nature. At very low frequencies, near cellular time scales, the gel's more viscous properties likely enable embedded cells to remodel the gel as needed for movement and tissue growth. The CNB appear to not affect this ability. The rheological properties of the gel indicate significant advantages to using this composite as a biomaterial for in situ tissue regeneration. The time sweep studies showed the gel does not further polymerize or depolymerize as time progresses and that the gel exhibits stability in its physical characteristics both with and without CNB content at physiological conditions of 37°C.

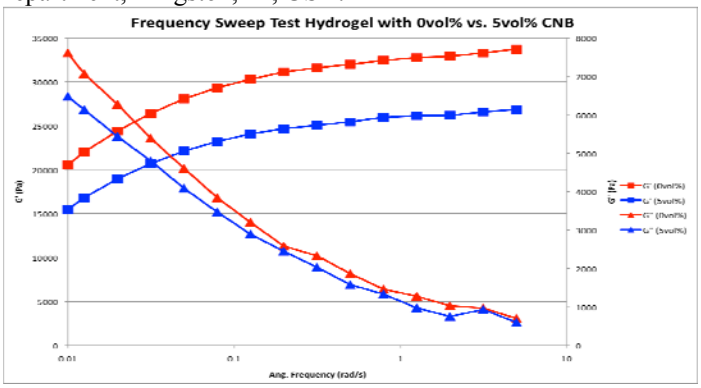

Figure 1. Frequency sweep test of poloxamer hydrogel containing 0vol% and 5vol% CNB at physiological conditions (37°C) showing G' (Pa), G'' (Pa) and a crossover from predominately elastic to predominately viscous regimes.

Conclusions: Considering the cardiac myocyte, cardiac fibroblast, and Neuro2A cells seeded in the hydrogels with higher CNB content in previous studies showed enhanced movement and proliferation compared to those in the 0vol% CNB hydrogel, the CNB seem to affect cellular movement within the gel by functioning in a similar capacity to an extracellular matrix with structural support and electrical conductivity for enhancing cell signaling. It is believed the CNB content within the hydrogel composite enhances the environment for cells by providing structural support similar to the extracellular matrix as a result of the physical conformation of the CNB, which resemble proteoglycans. The CNB have also been shown to provide electrical conductivity to the hydrogel composites, which further act to enhance the environment for the cells by allowing for cell-cell interaction, as well as the ability of cells, whether neuronal or cardiac, to sync together and demonstrate cell-cell interaction. The hydrogels with and without CNB have very useful features that enable it to be a potentially very successful scaffold for tissue regeneration.

References: [1] (Hunt NC. Biotechnol Lett. 2010;32(6):733-742) [2] (Marks WH. Proc. 38th Ann. NEBEC. 2012:392-393) For example: (Dodd LG. Am J Clin Pathol. 1990;93:141-144.)