FUNCTIONALIZATION OF A COPPER-CONTAINING NANO-BIOCOMPOSITE FOR SUBSEQUENT DEGRADATION AND BIOMEDICAL CONTROL

Anik Karan[1], Margarita Darder[2], Zach Norcross[1] and Mark A. DeCoster[1,3]

[1]Cellular Neuroscience Laboratory, Biomedical Engineering, College of Engineering and Science, Louisiana Tech University, 71270 Louisiana, USA
[2]Materials Science Institute of Madrid (ICMM), CSIC, 28049 Madrid, Spain
[3]Cellular Neuroscience Laboratory, Institute for Micro manufacturing, College of Engineering and Science, Louisiana Tech University, 71270 Louisiana, USA

Abstract: We have previously described the novel synthesis of a copper containing high-aspect ratio structure (cuHARS). The material is a biocomposite which is synthesized in an aqueous solution using the amino acid dimer cystine. Synthesis is carried out at physiological temperature, and the resultant cuHARS, scale from the nano- to the micro- dimension in size as confirmed using electron microscopy. To provide potential applications for these discovered materials, two approaches were taken in the current studies: 1) functionalization of the cuHARS with fluorescent nano- and micro-particles to be used for subsequent cellular tracking, and 2) integration of the cuHARS into natural products based matrices (cellulose), to provide stability and control for cuHARS degradation. To achieve these two aims, synthesized cuHARS, from the aqueous solution, were concentrated by centrifugation and then dried. Typical synthesis resulted in a yield of 5-7 mg of dried product. The known mass was then re-suspended at a concentration of 1 mg/ml in sterile, de-ionized water, for further functionalization and integration as described above. Purified cuHARS in water were stable for months-years without any apparent degradation or agglomeration as shown by light microscopy. In contrast, a concentration of 25 µg/ml of cuHARS in complete cell culture media (containing serum) was completely degraded (slowly) by 18 days under physiological conditions (37° C and 5% CO_2 incubator environment). This process could be accelerated in a concentration-dependent manner by use of the metal chelator ethylenediamine- tetraacetic acid (EDTA). Chelator accelerated cuHARS breakdown was measured using 50 mM- 50 µM EDTA, against a constant cuHARS concentration (25 µg). Breakdown was quantified using image analysis by measuring the disappearance of the biocomposites over time using bright-field microscopy. Given these stability and controlled degradation results, cuHARS were functionalized for tracking purposes with fluorescent nano- and micro-beads ranging from 20-500 nm in diameter. Binding was carried out using layer-by-layer, electrostatic techniques, and assisted by covalent chemistry. Stable integration of cuHARS into cellulose-derived matrices was successfully achieved through electrostatic assembly mixing cellulose micro- and nano-fibers and cuHARS in an aqueous (pulp mixture) phase, followed by 48 hours of drying at physiological temperatures. Once completely dried, the cellulose-cuHARS composite films could be transferred, and weighed and cut into usable pieces for biomedical applications. Finally, the cellulose-cuHARS composites maintained their integrated form after rehydration in water for at least 7 days at room temperature. These current studies demonstrate utility of a cuHARS biocomposite for applied biomedical (and potentially other) applications including: 1) a platform for biomedical tracking; and 2) integration into a 2D/3D matrix using natural products (cellulose).

Keywords: copper, cystine, biocomposite, chelator, cellulose, nano-composite, electron microscopy

Acknowledgements: This project is supported by a grant award from NSF: #1547693 and by joint sponsorship by the Fulbright Scholar Program and the Spanish Ministry of Education.