Fabrication and Characterization of Sub-Micron Plant-Derived Silicon Nanoparticles for Drug Delivery

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I. Introduction

Porous silicon (pSi) nanoparticles provide great potential as drug delivery vectors due to their high surface-area-to-volume ratio allowing for increased efficacy of surface functionalization and therapeutic loading capabilities. Fabrication of a class of materials which are smaller in size allows for increased efficiency when crossing the cell membrane for biological use. Such materials would ideally allow selective gene-editing in vitro, ultimately achieving successful treatment of disease while minimizing harmful side effects. Production of these materials through magnesiothermic reduction of plant-derived materials offers an economic advantage over anodized materials.

II. Methods and Results

A. Synthesis of pSi Nanoparticles

Figure 1: Synthesis of pSi nanoparticles from bamboo-derived silica extract

B. Characterization of Silicon Nanoparticles

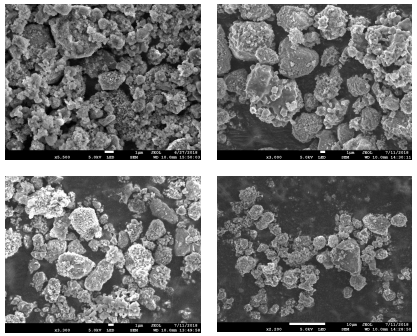

Figure 2: SEM images pSi Nanoparticles of approximately 0.5-15 um in size

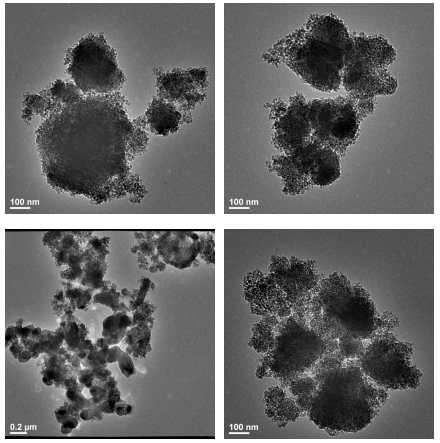

Figure 3: TEM images of pSi Nanoparticles of approximately 0.5-1 um in size

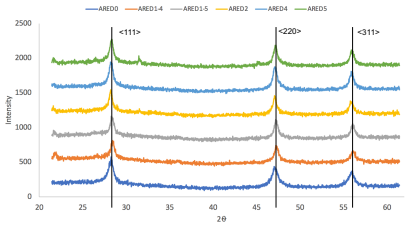

Figure 4: X-Ray Diffraction of pSi Nanoparticle samples (Consistent with Literature Values)[1]

C. Aminosilanization of pSi Nanoparticles

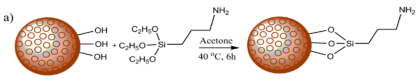

Figure 5: (3-Aminopropyl)triethoxysilane functionalization model[3]

Aminosilanization of the porous silicon material was carried out by submerging 6mg of pSi nanoparticles in a 4% (v/v) solution of APTES in acetone. The solution was then stirred and incubated at 40° C for 6 hours before collection by centrifugation and drying overnight in a vacuum

D. Characterization of APTES Functionalized Nanoparticles

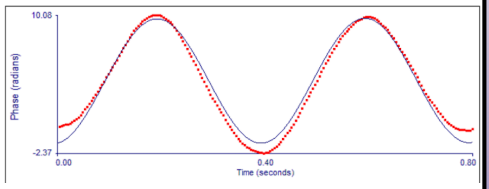

Figure 6: Zeta potential analysis of APTES functionalized pSi Nanoparticles (approx. 12.4 mV)

Figure 6 demonstrates the results of a zeta potential test carried out on functionalized pSi particles suspended via sonication in DI water. The positive zeta potential suggests the successful functionalization of the porous nanoparticles with aminosilane molecules whose primary amine functional group provides a method for further conjugation of the plant-derived material with various therapeutic agents This test was carried out with a voltage of 10 volts for 10 runs with 30 cycles per run.

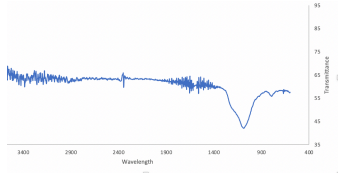

Figure 7: Infrared Spectrum of APTES functionalized pSi Nanoparticles[2]

Figure 7 displays the IR spectrum of APTES functionalized pSi Nanoparticles. The peaks displayed in the spectrum are consistent with literature values and suggest successful surface functionalization. The broad peak found between 930 and 1143cm^{-1} is consistent with that of Si-O stretching suggesting successful conjugation of the aminosilane group found in APTES

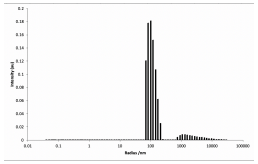

Figure 8: Dynamic light scattering analysis of APTES functionalized pSi Nanoparticles

Figure 8 demonstrated the results of a DLS test confirming the presence of sub-micron APTES functionalized product

III. Conclusions

The results presented here demonstrate that sub-micron plant-derived porous silicon nanoparticles can be successfully produced via high energy ball milling and magnesiothermic reduction. Further investigation regarding drug-loading capabilities, gene silencing, and fusogenic modification are necessary to fully evaluate the efficacy of these materials.

IV. References

1. Biogenic Nanostructured Porous Silicon as a Carrier for Stabilization and Delivery of Natural Therapeutic Species Nguyen T. Le, Jhansi R. Kalluri, Armando Loni, Leigh T. Canham, and Jeffery L. Coffer *Molecular Pharmaceutics* 2017 *14* (12), 4509-4514 DOI: 10.1021/acs.molpharmaceut.7b00638
2. Bragaru, Adina & Mihaela, Kusko & Radoi, Antonio & Danila, Mihai & Simion, Monica & Craciunoiu, Florea & Pascu, Razvan & Mihalache, Iuliana & Ignat, Teodora. (2012). Microstructures and growth characteristics of polyelectrolytes on silicon using layer-by-layer assembly. Central European Journal of Chemistry. 11. 205-214. 10.2478/s11532-012-0152-9.
3. JHANSI RANI KALLURI Sustainable Routes to Porous Silicon Nanostructures as Drug and Gene Delivery Vehicles PhD Dissertation Texas Christian University Fort Worth, TX May 2018

V. Acknowledgements

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