Creating Biocompatible Polymers Loaded With Porous Silicon Potentially For Drug Delivery

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Background

Drug delivery is the process by which medications are administered to the body. This is complex due to the difficulty of determining compounds that have the proper biocompatibility and permissibility to our human cells. Many medications are taken orally; however, there are situations where intravenous injection or subcutaneous delivery is required

Porous silicon are nanoparticles that have the unique properties of biodegradability and biocompatibility. This allows them to be potentially beneficial in achieving controlled drug release.[1] These will be attached to a film made of polycaprolactone (PCL) which is another biocompatible material with no known cytotoxic effects. Loading the film with the pSi allows for two-stage drug delivery and the refinement of films based on adjusting the percentage of the polymer in the solvent.

Attaching the porous Silicon to the depths of the pores was desired in order to achieve a high percentage pore fill which will maximize drug release. Creating films with high polymer concentration and a large surface area that are also non-toxic and not eliminated in vivo provide a new method of drug delivery,

Experimental Methods

- Porous silicon has a natural source which is from tabasheer power in bamboo plants and can purified into plant-derived porous silicon.

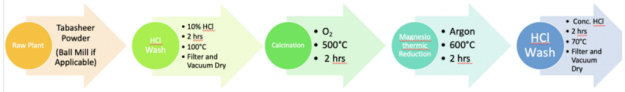


Figure I. Preparation of pdSi. Image produced by the Coffer group

Part 1. Making Porous Films

- Polycaprolactone which has the molecular formula (C6H10O2)n is a biodegradable and inexpensive hydrophobic ester that was dissolved in dichloromethane and dimethyl sulfoxide
- Upon casting, the solvent evaporates and dries and the polymer crystallizes around the non-solvent.

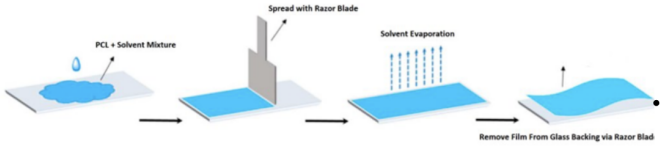
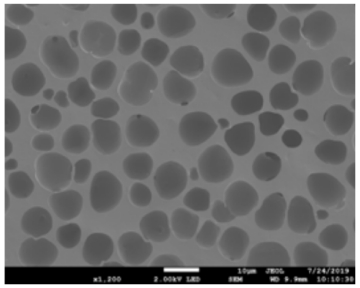


Figure II. Procedure to cast porous films

Image adapted from Liao, Zhengluan & Xia, Tifeng & Yu, Enyan & Cui, Yuanjing. (2018). Luminescent Metal–Organic Framework Thin Films: From Preparation to Biomedical Sensing Applications. Crystals. 8. 338.10.3390/cryst8090338. Modified by William Burnet

Part II. Determining the film that makes the most uniform sized pores

- The Scanning Electron Microscope (SEM) was used to determine the feret's diamter which is the largest distance between the sides of the pores in order to determine pore size.



- The scale bar determines the size of the pore using its pixelated distance.

Figure III. Film of 25% w/w PCL in DCM to DMSO. Scale bar is equivalent to 10 microns.

- Multiple films were made and evaluated with 25% w/w PCL in 9:1 DCM to DMSO leading to the pore size that would be large enough for porous silicon to deposit

% of PCL in DCM to DMSO	Average Pore Size (microns)
24.95	9.69
25.01	11.76
29.95 (film 2)	5.99
29.95 (film 3)	5.25

Table I. Different percentages of films in 9:1 DCM to DMSO

% of PCL in DCM to DMSO	Average Pore Size (microns)
24.92	4.08
25.08	2.49
34.66 (films 1 & 2 combined)	7.91

Table II. Different percentages of films in 8:2 DCM to DMSO

Part III. Covalently attaching the porous Silicon

- Covalent attachment of pSi to the films by 3-(aminopropyl)triethoxy silane functionalization followed by gluataldehyde treatment is necessary for the potentially drug loaded pSi to stay in the drug delivery media.

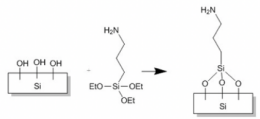


Figure IV. APTES functionalization of pSi

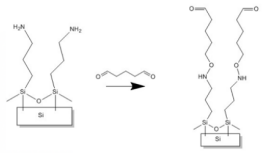


Figure V. Subsequent treatment of APTES functionalized pSi with glutaraldehyde

- Zeta potential measures the surface charge of nanoparticles in mV by tracking the rate of charged particles in an electric field. The graph displays the fit of the particles which should have been protonated under physiological conditions to the amplitude of positive charge.

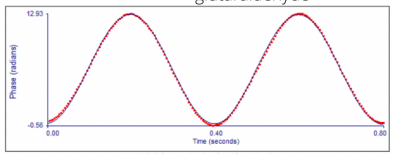


Figure VI. Zeta Potential Z= 14.19 (+/- 0.38)

Part IV. Covalently attaching the porous Silicon

- In order to increase percent pore fill and prevent aggregates on the surface, the films were dipped in water and sprayed with nitrogen gas.

Pore fill: 21.25%

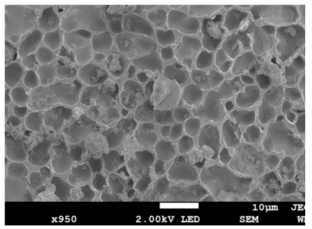


Figure VII. 25% w/w PCL in 9:1 DCM to DMSO film loaded with pSi sprayed with nitrogen and submerged in water. Scale bar is 10 microns.

aggregate Pore fill: 54%

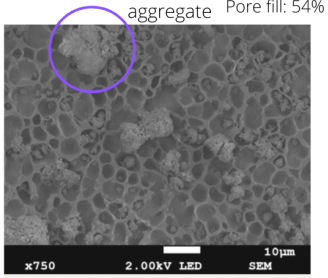


Figure VIII. 25% w/w PCL in 9:1 DCM to DMSO film loaded with pSi. Scale bar is 10 microns

Conclusion

The NIPS film that is 25% w/w PCL in 9:1 DCM to DMSO was the best film based on uniform and an appropriate pore size for the porous silicon that is loaded in it. When spraying the film with nitrogen gas and dipping it in water, the pore fill decreased but the number of aggregates and non-covalently attached porous silicon also decreased. This method is useful for removing excess porous silicon leading to the remainder of the silicon in the pores.

Future Work

The next step is to functionalize the surface of the film instead of the pSi in order to covalently attach the particles. The release kinetcics of camptothecin- a good model for hydrophobic drugs that has fluorescent properties- loaded pSi on the films and in spin will also be evaluated and compared to one another.

Acknowledgements

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References

1. Santos HA;Bimbo LM;Lehto VP;Airaksinen AJ;Salonen J;Hirvonen J; "Multifunctional Porous Silicon for Therapeutic Drug Delivery and Imaging." Current Drug Discovery Technologies, U.S. National Library of Medicine, pubmed.ncbi.nlm.nih.gov/21291407/.