New Silicon-Containing Composite Materials for Tackling Reactive Oxygen Species in Disease

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I. Introduction

Reactive Oxygen Species (ROS) are associated with a broad spectrum of diseases, ranging from bone loss to cancer. One strategy to combat ROS is to treat sources of such species in the body with materials capable of generating hydrogen and reacting with ROS to neutralize it. This project involves incorporating an H_2-generating material known as Calcium Disilicide ($CaSi_2$) into membranes of another H_2-generating material known as porous silicon for tandem antioxidant drug delivery. Porous silicon (pSi) is an important substrate in drug delivery as its nano-network of pores allows controlled loading of drugs. Our approach centers on the use of spark ablation to deposit $CaSi_2$ into the pSi. Both porous silicon and $CaSi_2$ are nontoxic and can be resorbed over time in vivo.

Sample Characterization / Evaluation:

- Scanning Electron Microscopy (SEM) - morphology
- In situ Energy Dispersive X-ray Spectroscopy (EDX) - % Ca
- Criterion of highest $CaSi_2$ loading % is used to determine the conditions for most efficient addition of $CaSi_2$ into the membrane.
- We have successfully incorporated $CaSi_2$ into pSi membranes.
- Current experiments are attempting to measure the amount of hydrogen produced synergistically to improve the performance of pSi to treat in situ ROS production.

II. Experimental

- To prepare $CaSi_2$/pSi, a piece of pSi membrane is fixed to substrate with a small drop of nail polish, and $CaSi_2$ powder is added.
- A capillary tube is placed on the pSi and spark ablated with a high-voltage Tesla coil, causing Si atoms on the porous membrane to vaporize along with $CaSi_2$ and the mixture resettles upon cooling.

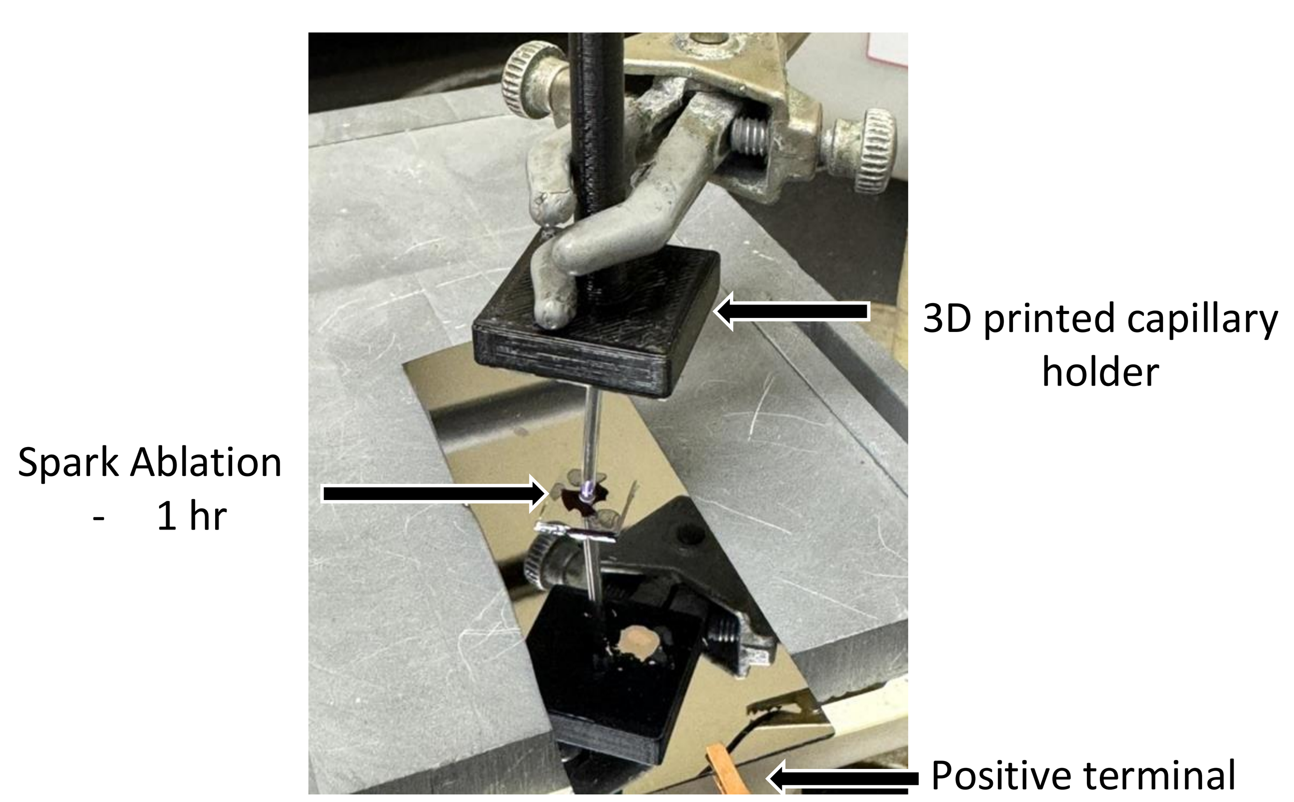

Figure 2- Experimental setup showing the 3D-printed capillary tube holder and spark ablation of $CaSi_2$ onto the porous silicon (pSi) membrane.

pSi / $CaSi_2$ Composite Fabrication

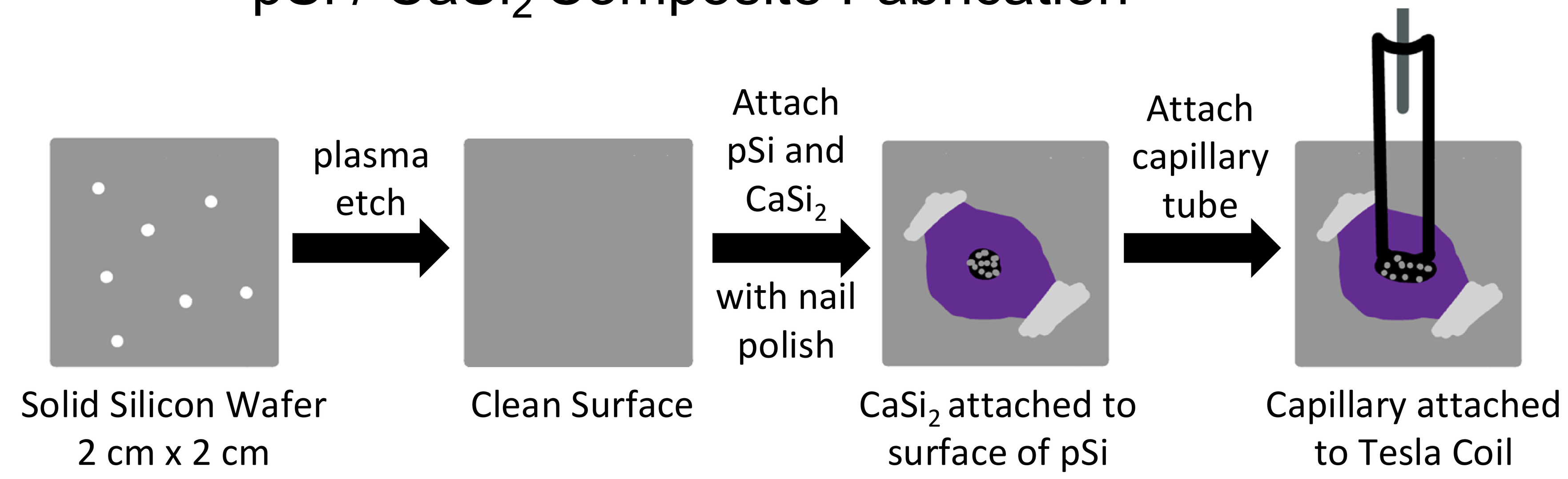

Figure 1- Schematic of $CaSi_2$ incorporation into porous silicon (pSi) via spark ablation using a Tesla coil.

III. Results

SEM/EDX Characterization

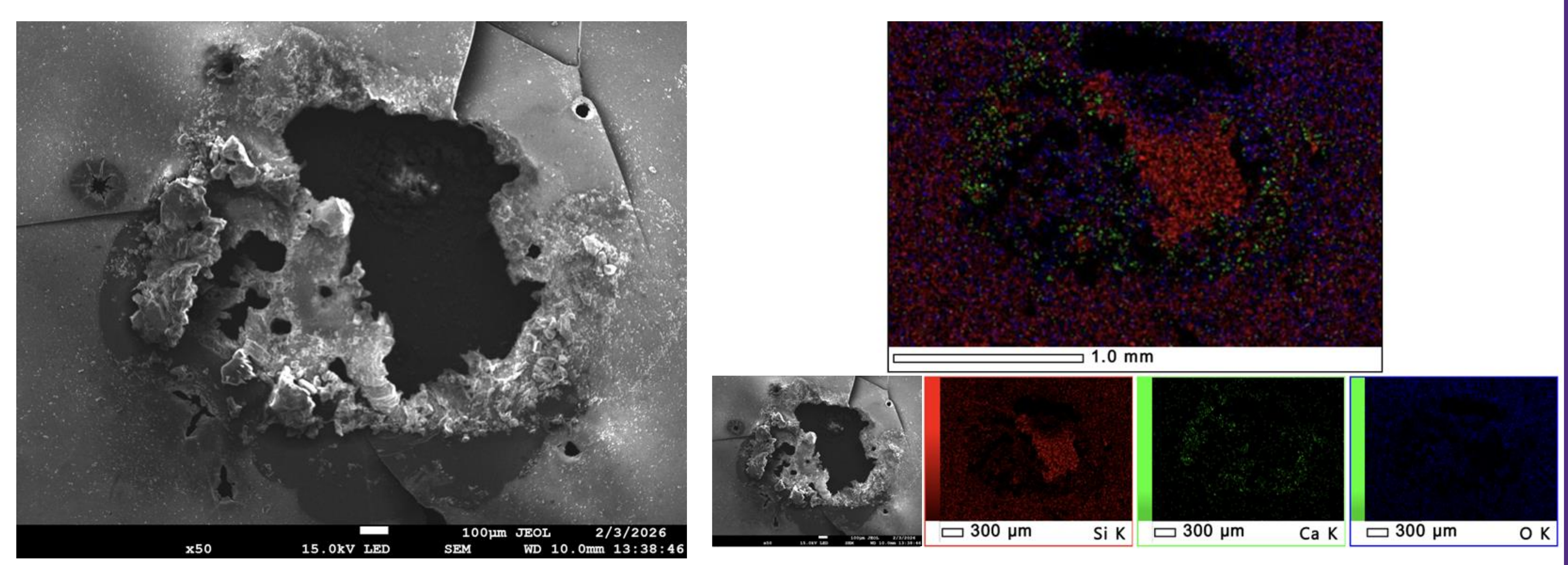

Figure 3- Left: pSi membrane after 1 hr of spark ablation. Right: EDX map showing calcium distribution on the membrane.

- Ca is concentrated around the ablated region in the EDX map, showing localized incorporation in the spark-ablated area of the pSi membrane.

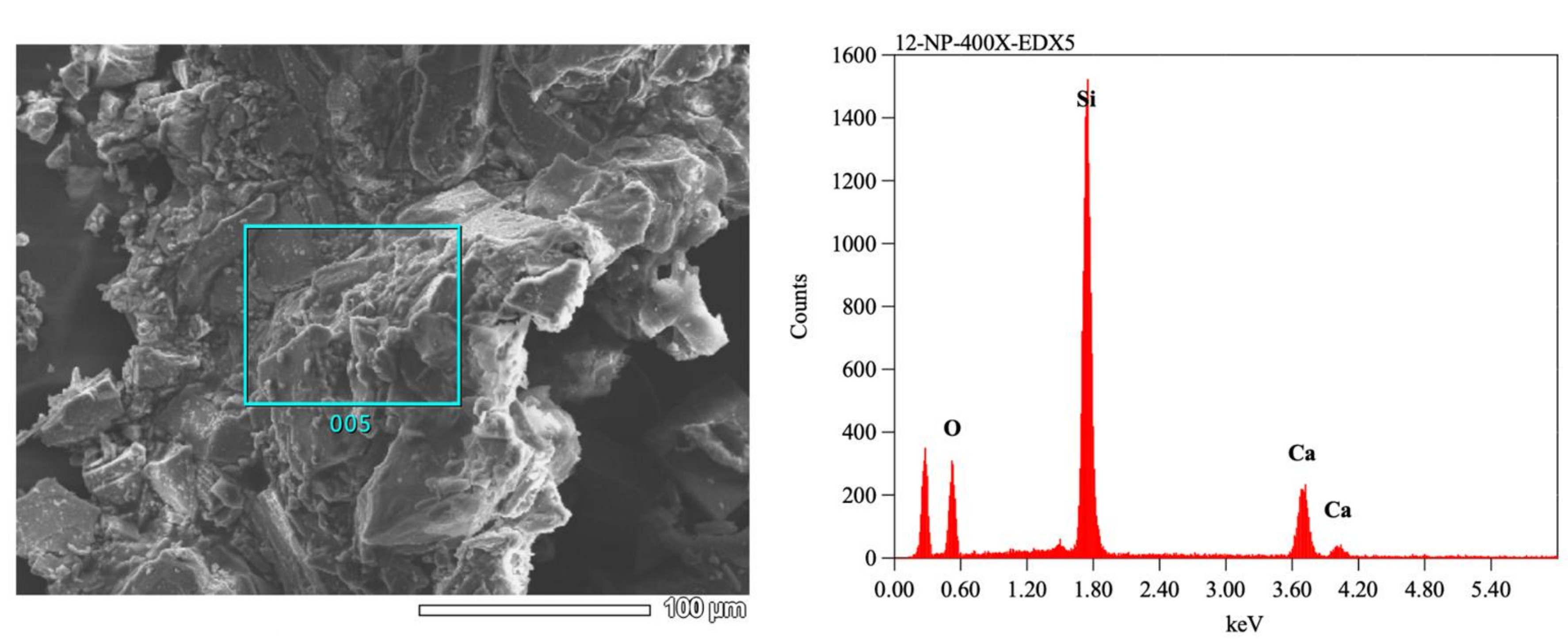

Figure 4- EDX spectrum of a $CaSi_2$-infused pSi membrane at 400× magnification showing a calcium mass percentage of 17.00%.

- Ca peaks confirm ~17% Ca in the sample.
- Similar morphology to $CaSi_2$ starting material at the ablated edge shows $CaSi_2$ incorporation.

IV. Discussion

The Calcium mass percentage in the membranes consistently is between 15–25%, indicating the method is reproducible. These results show that the porous silicon membrane is capable of successfully incorporating $CaSi_2$.

Table 1- Calcium mass percentage, membrane location, and morphology for four $CaSi_2$ pSi membrane trials

Trial	Ca % mass at 400x magnification	Where in sample most Ca is found	Morphology of highest Ca region
1	17.00	touching edge of small ablated hole in sample	raised surface, similar morphology to $CaSi_2$ starting material
2	22.88	aggregated cluster left of ablated hole	similar morphology to $CaSi_2$ starting material
3	19.71	touching edge of large ablated hole in sample	raised surface, similar morphology to $CaSi_2$ starting material
4	20.75	aggregated cluster left of ablated hole	similar morphology to $CaSi_2$ starting material

V. Future Work

- Focus will be on measuring hydrogen (H_2) generation to evaluate the performance of $CaSi_2$-infused pSi for treating in situ ROS production.
- H_2 generation from $CaSi_2$ will be measured while optimizing the experimental conditions.
- Once the method is consistent, the same conditions will be applied to $CaSi_2$-incorporated pSi membranes to compare hydrogen production and assess any improvement from incorporation.

Figure 5- Hydrogen-rich pen setup measuring H_2 (ppb) from $CaSi_2$ powder.

VI. References

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VII. Acknowledgments

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