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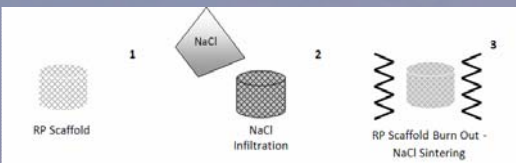
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## Introduction

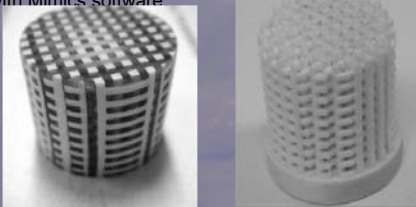
Porous materials are a very useful class of, lightweight engineering materials that can be fabricated with either a random or controlled pore structure. Current methods for fabricating various foams typically result in a random arrangement of the porous structure. By accurately controlling the pore architecture during fabrication, the overall properties of the porous foam structure can also be controlled. Manufacturing routes for foams with controlled, as opposed to random, pore architectures, are less well developed, and are typically more difficult and costly to produce. Sodium chloride (NaCl) is an ideal template material for casting various porous materials with lower melting point (801°C), due to its biocompatibility and ease of removal *via* dissolution. Various types of porous materials are still not able to be constructed using commercial rapid prototyping processes, and thus, an ordered NaCl template is a possible pathway to achieving periodic porous materials.<sup>1-3</sup>

## Template synthesis and characterization

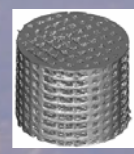
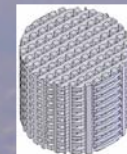
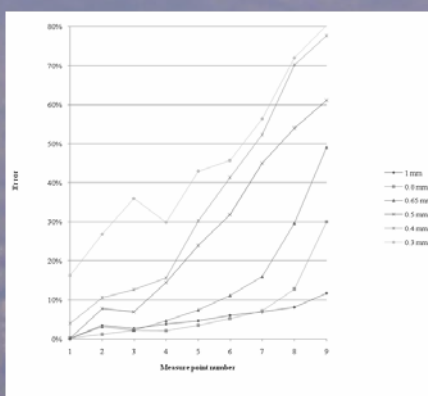
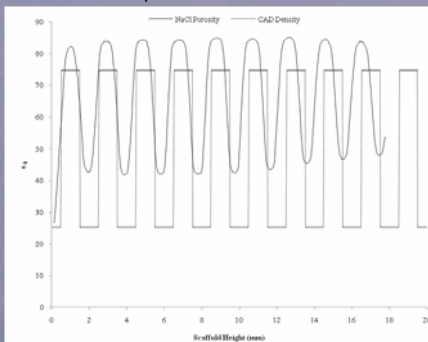
Micron scale NaCl particles were infiltrated into cylindrical polymer scaffolds fabricated from a CAD model using a commercial rapid prototyping (RP) machine. Two different types of RP scaffolds were made with external dimensions of  $\varnothing 20 \times 20$  mm high: (i) uniform  $1 \times 1$  mm square lattice structure, and (ii) gradient structure with varying pore size from 0.1 to 1 mm. After infiltration, the RP scaffold was removed by combustion using a heat treatment.



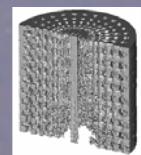
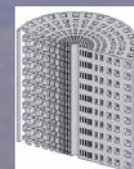
Micro-computed tomography ( $\mu$ -CT, SkyScan 1172) was used to evaluate porosity and dimensional errors in moving from the RP to NaCl template structures. A series of cross-sectional bitmap images were obtained with isotropic pixel size of  $37 \mu\text{m}$  as slices through the height of the samples. For the error measurements on the gradient structures, each pore size group (30 pores) were isolated by cropping. The individual pore groups were measured at nine points throughout the sample height and each measurement consisted of seven images in the middle of each lattice. Whereas for the lattice structures, the entire image area was measured from top to the bottom. The porosity and error measurements were made by converting images to black and white pixels and masking a set area for the measurements. ImageJ software was used for porosity and error measurements. A 3-D reconstruction of the  $\mu$ -CT images was performed with Mimics software.



3-D computer reconstructions of the sodium chloride scaffolds were used to compare the initial density of the CAD models used to print the RP models to the density of the NaCl template structure. The porosity of the lattice structure compared to the CAD structure was plotted over the sample height. The porosity was found to be constant for regions of high pore volume, but was found to increase with scaffold height in regions with lower pore volume. The error between the CAD model was greatest for the low porosity area, ranging between 43-47% and, therefore, on average was 20% greater than the porosity of the corresponding idealized CAD model. For the higher pore volume area, the porosity of the idealized CAD model was 75% and the template porosity was found to be 8% greater. It was also found that the 20 mm long template ended 0.5 mm shorter, as a result of the pressure applied to the RP scaffold while infiltrating it with the NaCl paste.



For the pore gradient scaffold, a series of individual pores were analysed at nine points through the height of the scaffold. It was found that smaller pores resulted in greater error from the original CAD design, as 1 mm pores had just over 10% maximum error, while it was over 80% for 0.3 mm pores. Pores in the range  $\varnothing 0.65$  to 1 mm have very similar infiltration properties in the top half of the scaffold (Fig. 6). Pores with sizes of  $\varnothing 0.1$ ,  $\varnothing 0.15$ ,  $\varnothing 0.2$  and  $\varnothing 0.25$  mm were not infiltrated by the NaCl, but it was also found that some of these smaller diameter pores were already blocked in the RP scaffold due to reaching the lower resolution limit of the RP process, suggesting improvements are required in RP resolution limits to make such fine structures.



## Conclusion

- A porous NaCl template with controlled porous internal structure has been created.
- The sodium chloride was infiltrated successfully into pores  $\varnothing 0.3 \times 0.3$  mm and larger.
- Larger NaCl struts did obtain less error from ideal model.
- RP scaffolds did condense non-reversible due to pressure applied when infiltrated with NaCl paste.

## References

1. Fr.-W. Bach, D. Bormann, P. Metfoam2003, P215-218, MIT 2003
2. P. Hariraksapitak, O. Suwanton, P. Pavasant, P. Supaphol., Polymer, 2678-2685(2008).
3. J. Zhang, L. Wu, D. Jing, J. Ding, Polymer 4979-4985(2005).

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