Non-linear Analysis of Deformation Behavior of HA/PLCL Porous Bio-composites

F. Hazwani[1,2,3], M.Todo[2,3] , N. Aiman[2,3]
[1]Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Fukuoka, Japan.
[2]Research Institute of Applied Mechanics (RIAM), Kyushu University, Fukuoka, Japan.
[3]Department of Molecular and Material Sciences, Kyushu University, Fukuoka, Japan.

INTRODUCTION

- Bioceramics such as hydroxyapatite (HA) are extensively used in the scaffold development for the reconstructive treatment of bone defects.
- However, their low mechanical properties have become problems in real surgical situation.
- In this study, HA based scaffold incorporating PLCL biodegradable polymer was developed to enhance the mechanical properties of pure HA scaffold.
- In order to predict the mechanical behaviour of the composite scaffold, two theoretical models were be developed and analyzed.

Model I

The material is assumed to have non-linear deformation using the Hollomon's equation:

$$\sigma = F\varepsilon^n$$

The loading-point displacement δ of a bending beam is given by:

$$\delta = KP^{1/n}\begin{bmatrix} n(L-x)^{(2n+1)} \\ +(2n+1)L^{(n+1)/n}x \\ -nL^{(2n+1)/n} \end{bmatrix}$$

where,

$$K = \left[\frac{n(n+2)2^n}{(n+1)(2n+1)H^{n+2}BF}\right]^{1/n}$$

Model II

The material is assumed to have elastic-plastic deformation:

Elastic deformation ($0 \le P \le P_y$):

$$\delta_e = \frac{PL^3}{6EI}$$

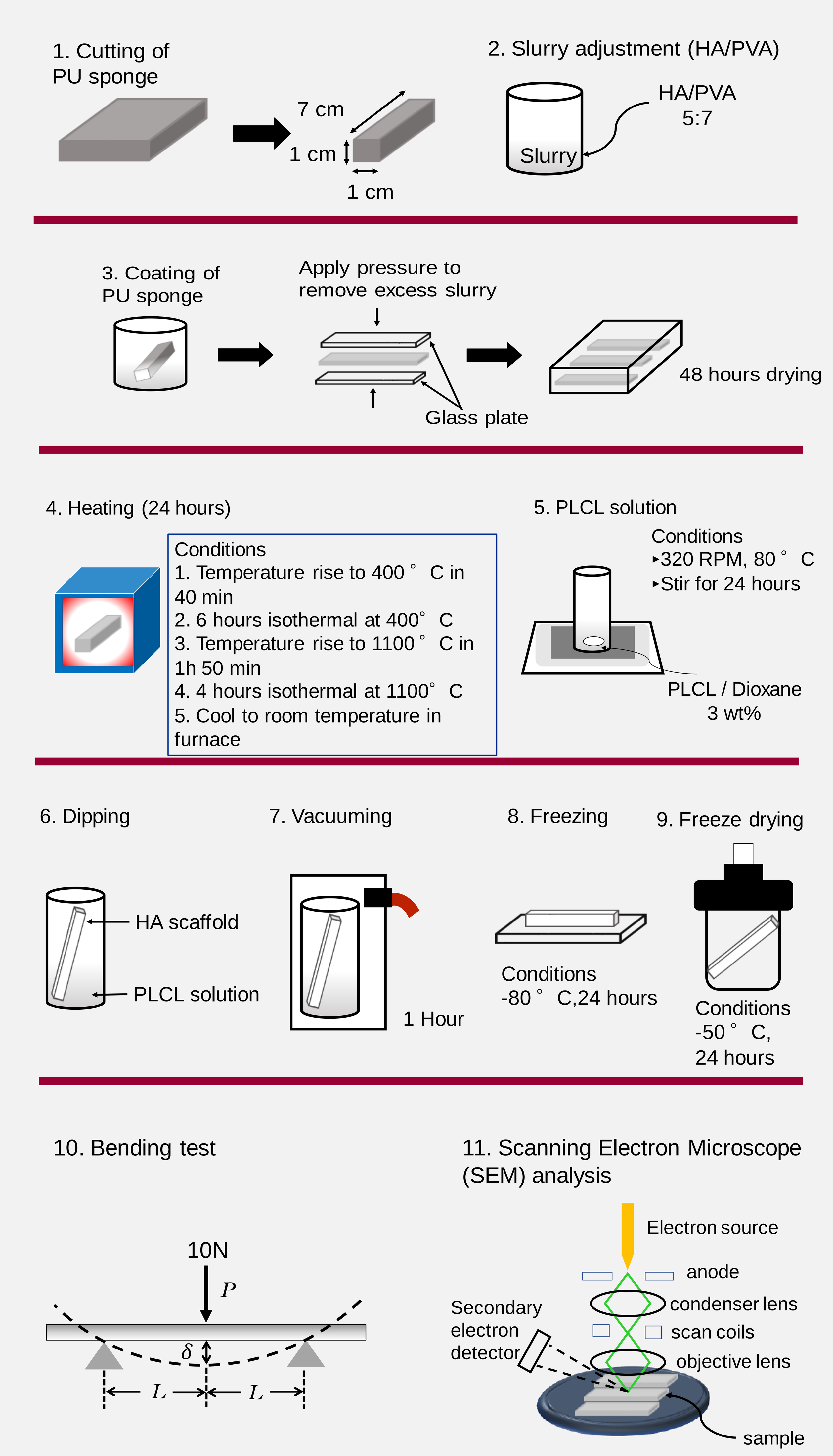
Plastic deformation ($P \ge P_y$):

$$\delta_p = KP^{\frac{1}{n}}\begin{bmatrix} n(L-x)^{(2n+1)} \\ +(2n+1)L^{\frac{(n+1)}{n}}x \\ -nL^{(2n+1)/n} \end{bmatrix} + \delta_y$$

where,

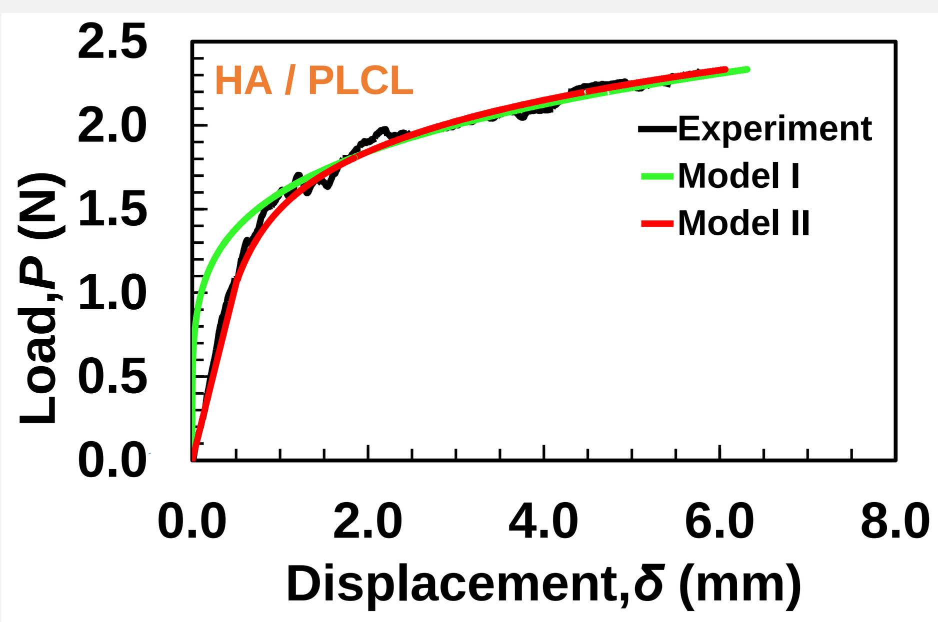
$$K = \left[\frac{n(n+2)2^n}{(n+1)(2n+1)H^{n+2}BF}\right]^{1/n}$$

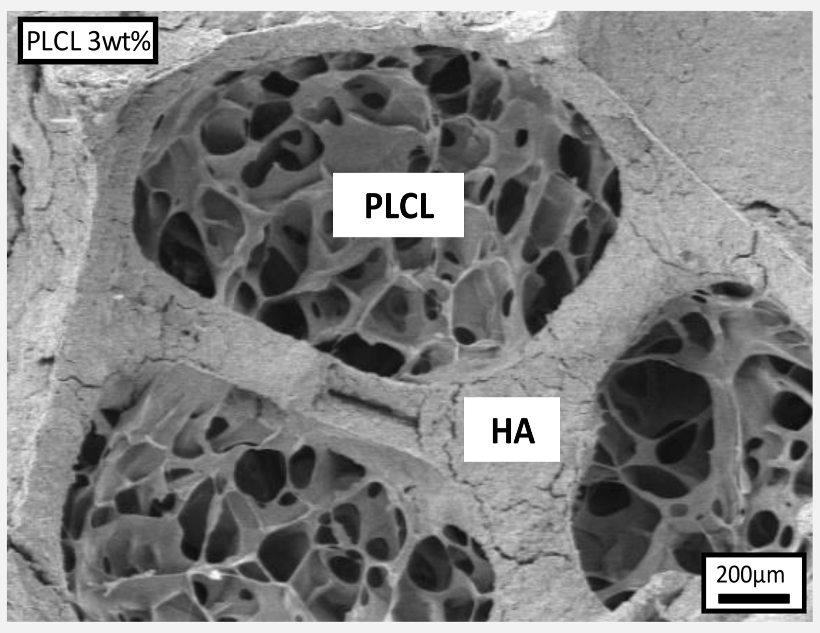
METHODS AND MATERIALS



RESULT AND DISCUSSION

- The introduction of PLCL polymer phase into the HA frame structure has provided ductility, thus preventing the entire structure from catastrophic fracture passing the yield load.
- The scaffold produced two types of well-developed interconnecting pore structure, i.e. (i) initial pore created by HA material and (ii) honeycomb-like PLCL pore formed during the freeze-drying process.
- The scaffold was able to provide porosity and average outer pore size more than 80% and 400µm, respectively, which is ideal for cell adhesion and nutrient transport.
- The morphological structure of HA/PLCL shows two layers of interconnecting pores where the addition of polymer has enhanced the mechanical properties by providing ductility.
- HA/PLCL material is observed to have elastic-plastic deformation where Model II depicts better accuracy compared to Model I with 92.96% and 88.18%, respectively.





CONCLUSION

- The structural stability of brittle HA and its mechanical properties has been improved by introducing PLCL polymer
- It is confirmed that the HA/PLCL scaffold exhibits elastic-plastic deformation.
- The strain hardening coefficients invoked in both models have become significant to address the non-linearity.
- Model II shows higher accuracy when compared to Model I and may be useful in predicting the stress-strain behavior of a non-linear deformation of a material.

REFERENCES

- A. G. Mikos and J. S. Temenoff, *Electron. J. Biotechnol.*, vol. 3, no. 2, pp. 114–119, 2000, doi: 10.2225/vol3-issue2-fulltext-5.
- M. C. Azevedo, R. L. REIS, M. B. Claase, D. W. Grijpma, and J. Feijen, *J. Mater. Sci. Mater. Med.*, vol. 14, no. 2, pp. 103–107, 2003.
- M. Todo, P. Yos, T. Arahira, and A. Myoui, *Biomater. Tissue Technol.*, vol. 2, no. 1, pp. 1–8, 2018.

九州大学
KYUSHU UNIVERSITY

Kyushu University Program for Leading Graduate Schools Advanced Graduate Program in Global Strategy for Green Asia

Acknowledgements
The author would like to thank the Green Asia Program for Leading Graduate School, Kyushu University for the financial support and Research Institute for Applies Mechanics, Kyushu University for the facilities provided to conduct this study.

Fatin Hazwani Binti Mohamad Azahar
3ES18115K@s.kyushu-u.ac.jp