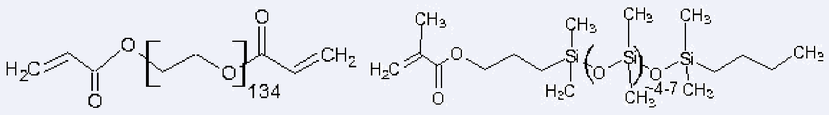
The Development of Artificial Cornea Using Silicone-Hydrogel Material

Hsin-Yi Duan[1], Steven Sheng-Shih Wang[1,*], Chi-An Dai[1,*], Josephine W. Wu[2,*]
[1]Department of Chemical Engineering, National Taiwan University
[2]Department of Optometry, Central Taiwan University of Science and Technology

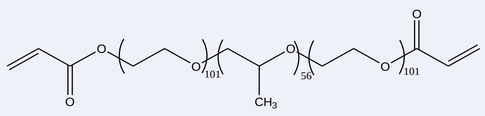
Abstract

Corneal opacification from disease or trauma is estimated to affect more than 10 million people worldwide, and corneal transplant has become the most common surgical treatment to recover patients' vision. However, corneal transplant is not applicable for the patients with high-risks, and thus, artificial cornea becomes a viable option. Artificial cornea is divided into two parts: the optical center and a ring of keratoprosthesis skirt. The keratoprosthesis skirt fixes the artificial cornea to the host sclera and serves to transfer nutrients and maintains ocular surface metabolism. In this study, three hydrogel components were tested as potential materials to be used for the construction of keratoprosthesis skirt: 1) polyethylene glycol diacrylate (PEGDA) and 2) poloxamer 407 diacrylate (P407DA) make up the high porosity framework, while 3) silicone-containing mono-methacryloxypropyl terminated polydimethylsiloxane' s (mPDMS) properties improves oxygen permeability and mechanical strength. Based on the swelling test, hydrogels containing mPDMS material were more hydrophobic than the ones containing PEGDA. Direct observation under the scanning electron microscope (SEM) and mercury porosimeter revealed that all hydrogels possess porous structure with open pores. The application of different amounts of P407DA can regulate pore size and porosity. Results from the dynamic mechanical analysis revealed that only the hydrogels containing PEGDA and mPDMS have larger shear storage modulus, and increasing amount of P407DA led to a decrease in the shear storage modulus. The accelerated oxidation results showed that the hydrogels containing mPDMS have greater stability (longer degradation time) than those containing PEGDA.

Material



PEGDA mPDMS

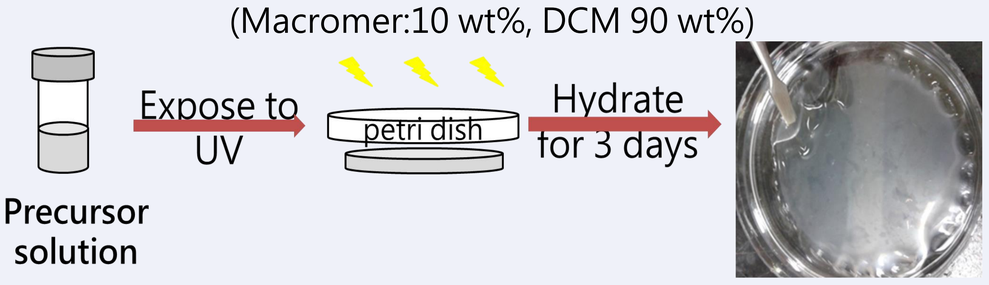


P407DA

Method

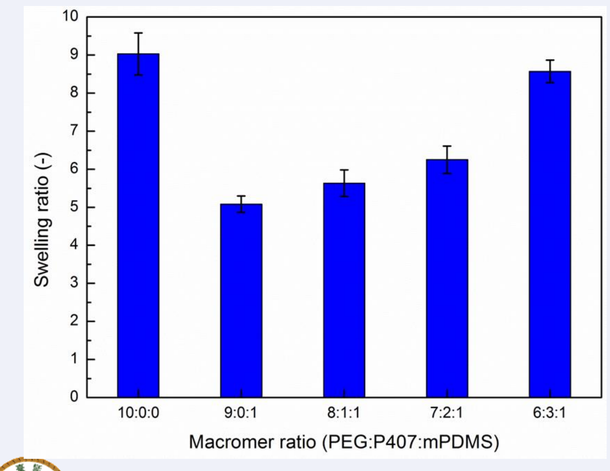
Sample name	PEGDA	P407DA	mPDMS
10:0:0	10	0	0
9:0:1	9	0	1
8:1:1	8	1	1
7:2:1	7	2	1
6:3:1	6	3	1
Total Ratio	10%		

(Macromer:10 wt%, DCM 90 wt%)



Results

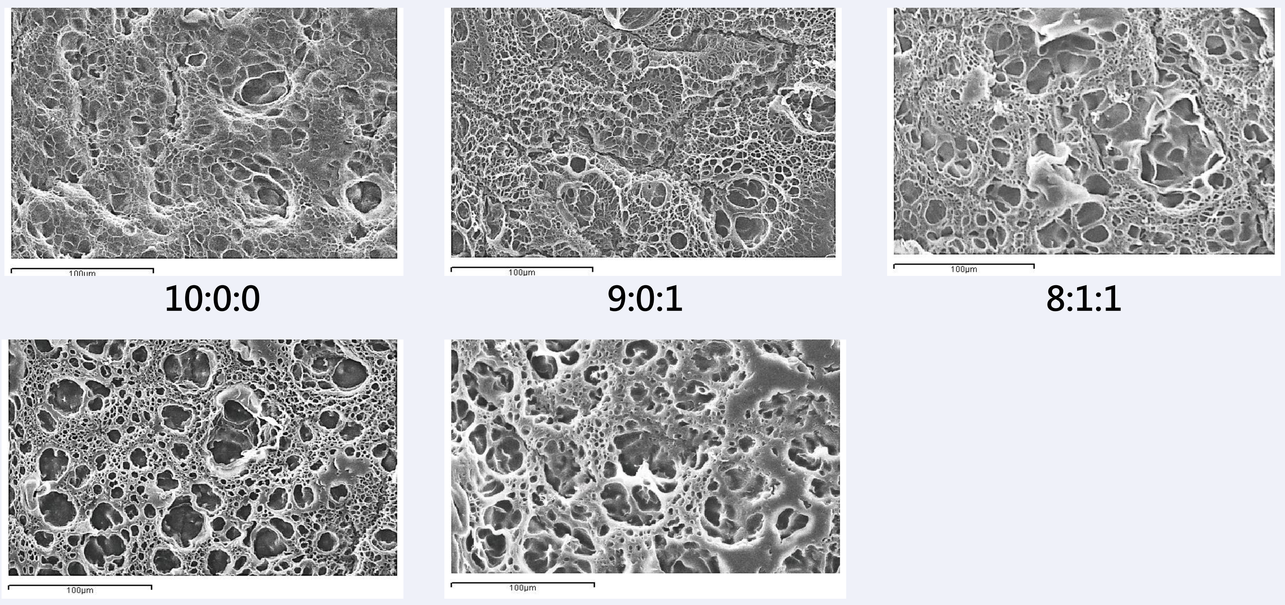
1. Equilibrium swelling test



The swelling ratios of hydrogel were observed to significantly drop with the addition of only mPDMS. However, the ratios were found to regain upon further addition of P407DA, and the increase in swelling ratio was positively correlated with the amount of P407DA macromere added.

Results

2. Pore morphology

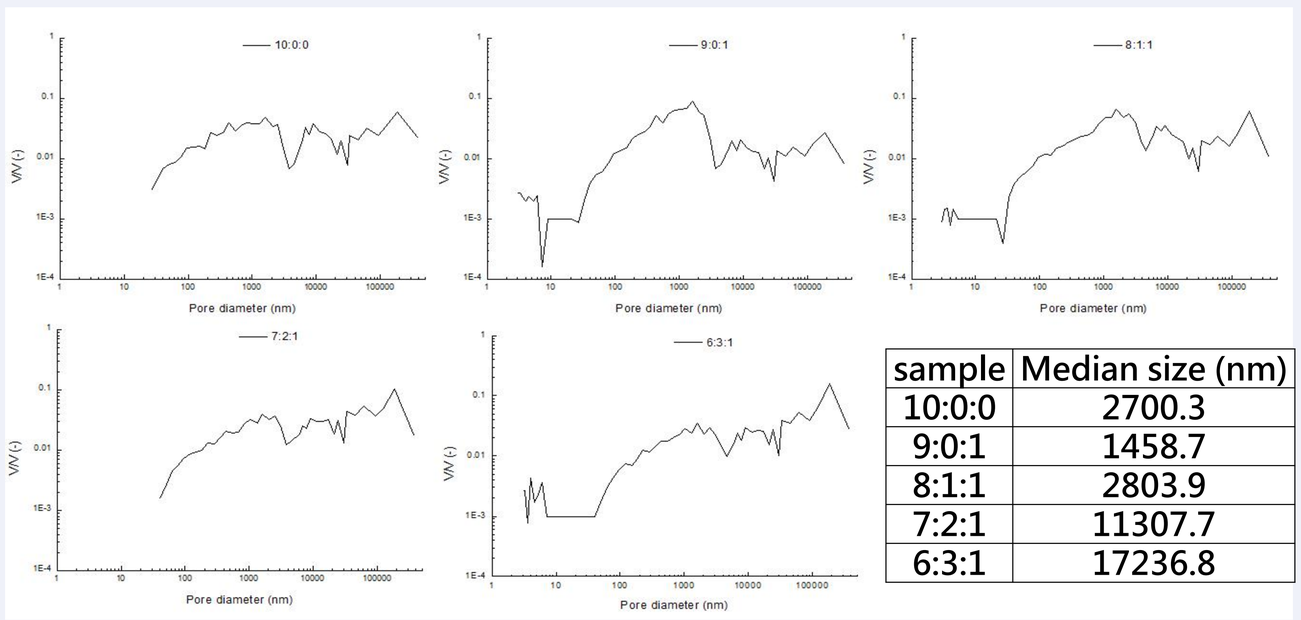


10:0:0 9:0:1 8:1:1

7:2:1 6:3:1

When mPDMS was added, pores become much more than those with only PEGDA macromer existed in the hydrogel. As P407DA increased, pores became larger. All the hydrogels with different macromer ratio have micro-order pores.

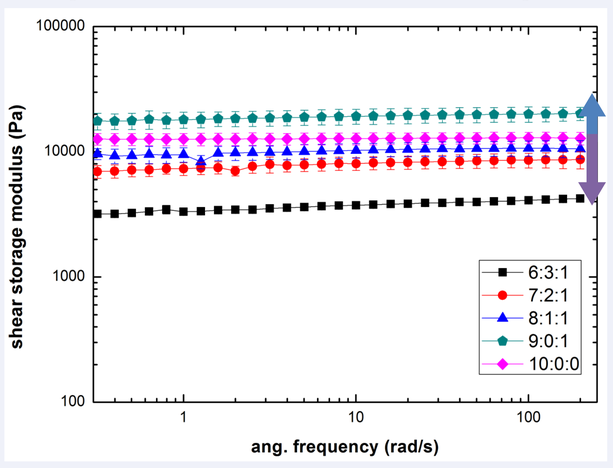
3. Pore Size and Distribution



sample	Median size (nm)
10:0:0	2700.3
9:0:1	1458.7
8:1:1	2803.9
7:2:1	11307.7
6:3:1	17236.8

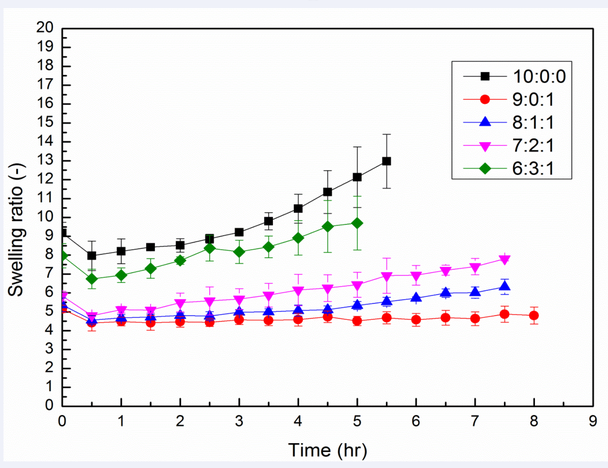
When mPDMS was added, small pores started to form, and thus the size of pores in hydrogel became more inhomogeneous. However, the pore size became larger as the amount of P407DA was increased.

4. Dynamic Mechanical Analysis



The shear storage modulus in the samples was not changed by varying the angular frequency.
The hydrogel with the PEG:P407:mPDMS ratio of 6:3:1 showed the smallest shear storage modulus.

5. Oxidative Degradation Test



The swelling ratios of the mPDMS-containing hydrogels remained unchanged for a longer time than those of the PEGDA hydrogels, indicating their better structure integrity under free radical condition.

Conclusions

Our results showed that the silicone-based materials can be used to promote the mechanical strength and prolong the degradation time. In conclusion, we believe that these silicone-containing hydrogels with the high porosity and large open pores have the potential to serve as the raw material for keratoprosthesis skirt of the artificial cornea.