BETWEEN THE SHEETS – MECHANICAL PROPERTIES AT THE INTERFACE OF TWO POLYMER GELS

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BACKGROUND

Although polymeric matrices are commonplace in bioengineering applications, composite systems, with distinct layers, are difficult and expensive to manufacture. Composite biomaterials would be useful to control cell spacing, regulate immune response, or for controlled release applications. For example, poly(ethylene glycol) (PEG), has been used in recent studies as a composite with pentaerythitol triacrylate (PETA) for controlled release from highly crosslinked gel spheres (Mellott). Because of its use in composite materials, as well as its ability to be easily chemically modified and control cell adhesion, our study has focused on photocrosslinked PEG hydrogels. In order to form these gels into composites, mechanical testing must be completed to describe the properties at the interface between the layers. Therefore, this study focused on the mechanical properties at the interface of two PEG gels that were crosslinked at two different times. Determining the tensile strength of these composite interfaces could aid in future fabrication of a composite matrix to be used in various biomaterial applications.

GOALS

More investigation into layering these materials, including mechanical changes that happen when crosslinked at different times, was performed in order to further elucidate if PEG is an appropriate material for composites. Specifically, this project:

- Examined the strength of gels crosslinked for different lengths of time
- Crosslinked part of the gels at two different times and examined the strength of the boundary
- Examined how overall crosslinking time affects boundary strength
- Examined the distance between the yield point of the gel and the position of the subsequent crosslinking interface.

MATERIALS AND METHODS

Solutions of 10% and 15% poly(ethylene glycol)-diacrylate (Shearwater) (PEG-DA) solutions were prepared by dissolving PEG-DA and photo/initiator (Igracure, 10%(w/w), CIBA Geigy) in diH_2O (Bryant & Anseth). Enough PEG-DA solution was placed into 4" by 4" glass plates separated by 1mm thick PTFE sheet to completely fill the mold. Exposure to UV light for 20 min (4 mW/cm^2, 365 nm) crosslinked the solution into a gel. The hydrogels were then cut into tensile test specimens with test sections 5 mm wide and 25 mm long(defined by testing apparatus) (Figure 1).

After cutting, the hydrogels were washed in diH_2O for 5 days. To prepare gels that had been crosslinked at different times, a portion of the test section was crosslinked while covering the rest with a material that will absorb the UV light as shown in Figure 1b (black cardboard was used to absorb light). Different amounts of the test section were covered and secondarily crosslinked to determine if the different crosslinking times or position affected the mechanical properties of the gel. Three different positions were investigated, with material covering 1/3, 1/2 and 2/3 of the test section. These tests were completed to determine whether additional layers of polymer could be crosslinked to an already crosslinked matrix. A control specimen was also fabricated by cutting a specimen from the portion of the mold that was uncovered for the entire crosslinking period. This specimen is shown in Figure 1a.

To examine mechanical properties of the material, five specimens of each primary and secondary crosslinking fraction were tested in order to obtain results that can be accurately compared and analyzed. The tensile strength of these crosslinked hydrogels was tested using a MTS 858 Bionix II (MTS Systems Corporation, Eden Prairie, MN). A plot of stress vs. stain was formulated, and the elastic modulus and ultimate stresses of the hydrogels were determined. The distance between the yield point and the crosslinked border was also measured, and calculated as a percentage of the total gage length of the test section.

RESULTS

Figure 2 demonstrates typical data for 10% and 15% PEG gels. The control specimen for each case was formed at the same time as the 1/2 crosslinked specimen (Figure 1). In this case, the ultimate strength of the 15% PEG half specimen and control specimen are ~89MPa and 93Mpa, respectively, and the elastic moduli are approximately 309MPa and 298MPa. The 10% PEG half specimen and control specimen have ultimate stresses of 46MPa and 35MPa and the elastic moduli are 129MPa and 71MPa. (Figure 2) Each specimen exhibited abrupt failure without a considerable yield region on the stress-strain curve. Preliminary calculations on the distance from failure to the crosslinked interface was considerable enough to warrant further investigation into the layering of these matrices. For example, the gels with borders at the middle of the specimen (1/2 distance of the test section) showed an average distance from the border ~8.26mm, which corresponds to ~33% of the entire test section length. This data shows that the fractionally crosslinking may not negatively affect the mechanical properties of the matrix.

CONCLUSION

The results of this study show encouraging evidence that layered PEG matrices may be fabricated using subsequent crosslinking of polymer layers. Further study will be performed to determine if length of UV exposure could affect the mechanical properties of the gel. In addition, different polymers will be crosslinked together and tested for mechanical strength in order to better represent the composite polymeric layers that would be used in various biomaterials applications.

REFERENCES

1 Mellott, Michael B., Searcy, Katherine, and Pishko, Michael V., "Release of Protein from highly cross-linked hydrogels of poly(ethylene glycol) diacrylate fabricated by UV polymerization." Biomaterials, Vol. 22, pp 929-941, 2001.

2 Bryant, Stephanie J and Kristi Anseth. "The Effects of Scaffold Thickness on Tissue Engineered Cartilage in Photocrosslinked Polyethylene oxide) Hydrogels." Biomaterials. 22(2001) 619-26.

FIGURES

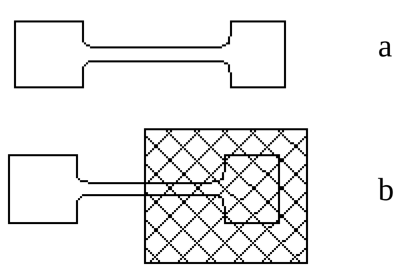

Figure 1

Sketches of a) control specimen prepared by crosslinking entire area and b) specimen prepared by crosslinking half of the area and covering the other half with a UV absorbing material.

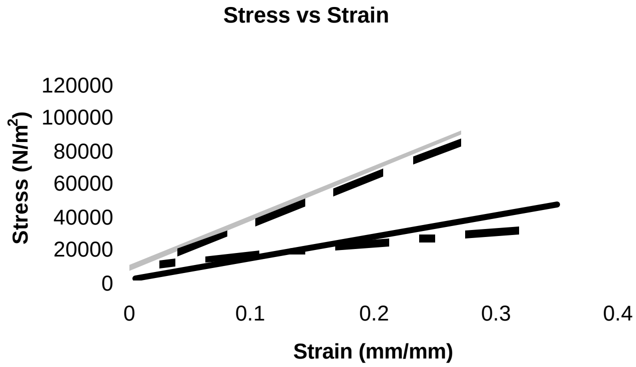

Figure 2

Gray and equal dashes represent 15% Peg gel fractionally crosslinked by halves and 15% PEG gel crosslinked fully as a control respectively. Full line represents 10% half crosslinked specimen and uneven dashed represents 10% control specimen.