QUANTIFICATION OF VISCOUS DISSIPATION PROPERTIES OF HEMA HYDROGELS AS A TOUGH BIOMATERIAL

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Introduction

Hydrogel systems are widely used in biomedical applications. Since synthetic hydrogels generally have weak mechanical properties and show brittle behaviour, their use is then limited to non load-bearing applications. The weak mechanical performance of chemically cross-linked hydrogels mainly originates from their very low resistance to crack propagation. This is explained by the lack of an efficient energy dissipation mechanism in the gel network. To obtain a gel with a high degree of toughness, its overall viscoelastic dissipation has to be increased (Tuncaboylu 2011). In this study, we characterized the dissipation properties of different HEMA based-hydrogel as hydrophobic networks with high dissipation.

Methods

We prepared HEMA hydrogels with different cross-linkers (EGDMA, TEGDM, PEGDM 550, PEGDM 750) via UV polymerization. We also varied the concentration of water in the hydrogel (20, 40, 50%). Dissipation of hydrogel samples was measured by calculating the hysteresis curve obtained from cyclic compression loads at 1 Hz and 15% deformation. We also calculated the damping ratio (the ratio of the dissipation to total input work) as a measure of how the damping properties of material change comparing to its stiffness. The damping ratio can be a measure of resistance to crack propagation (Zhao-2011).

Results

Figure 1 shows the dependency of dissipation of HEMA hydrogels to cross-linker and water ratio. Dissipation decreases by increasing the cross-linker chain length and the water ratio. The hydrogels having 6% cross-linker have a higher dissipation than 4%.

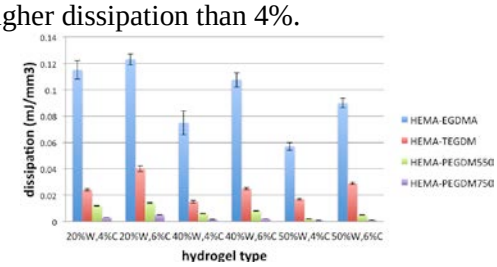

Figure 1: dissipation of HEMA hydrogels with different cross-linkers and water ratios.

Figure 2 shows that damping ratio of hydrogels also decreases with increasing cross-linker chain length. Interestingly, the damping ratio stays almost constant with increasing water ratio and cross-linker concentration in spite of the decrease of the gel stiffness.

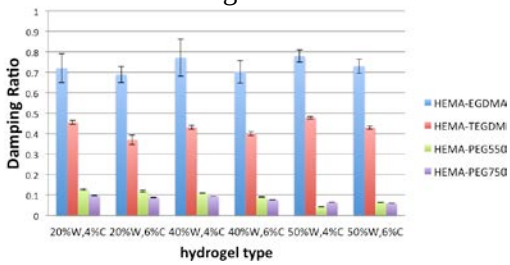

Figure 2: damping ratio of hydrogels under mechanical loading.

Discussion

Our results show that the damping properties of HEMA-based hydrogel are strongly affected by the choice of cross-linkers. Using EGDMA as cross-linker leads to dramatically higher dissipation. These hydrogels can keep their high damping properties when they are stiff, highly cross-linked and with little water content or when they are soft with higher water content and weakly cross-linked. With the possible variation of these properties this material can be used as a biomaterial in variety of load bearing tissues, where different stiffness is required, like nucleus pulpous or articular cartilage. In addition to damping ratio, comparing the hysteresis at different loading cycles can be another measure of micro-crack propagation in materials (Diani,2009). For our HEMA hydrogels, we found that the hysteresis curve did not change with the number of loading cycles. This suggests that the hysteresis is due to viscous dissipation not micro-crack propagation that can lead to material softening and fracture.

References

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