

Functional microcapsules with inorganic-organic thick shells using sol-gel chemistry

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Abstract

One of the challenges in encapsulation is to independently control the chemical and mechanical properties of the microcapsule shells. For instance, for some encapsulations it may be desirable to achieve chemical protection of the encapsulant from oxidative [1] or irradiative stresses [2] via the addition of protective agents to the shell. But, the addition of such materials often affects the mechanical properties of the shell as well as the rheological and interfacial properties of the shell precursor, and therefore the encapsulation process. Through a sol-gel method, we propose a technique for forming microcapsules with inorganic-organic hybrid shells, which can be independently tuned for mechanical and chemical properties by adjusting the organic and inorganic precursors, respectively.

A silane-functionalized poly(propylene) glycol macromonomer was selected due to its optical transparency, wide range of solubility, low cost, and biodegradability/biocompatibility. For bulk tests the macromonomer was simply cast as a film and exposed to humidity for several hours. By varying the molecular weight or degree of functionalization, one can achieve two orders of magnitude variation in tensile strength and Young's modulus. Meanwhile, the addition of inorganic sol-gel precursors such as tetraethyl orthosilicate (TEOS) or titanium (IV) isopropoxide (TIP) had no effect on mechanical properties. Additionally, because the polymer mesh size is defined by the molecular weight of the macromonomer, the gel has predictable permeability for encapsulants of known hydrodynamic radius.

It was also found that these sol-gel precursors could gel in-situ using oil-templated techniques. A capillary microfluidic approach was used to form w/o/w double emulsion templates that are in turn converted into microcapsules [3]. Macromonomer was dissolved in oils that may diffuse through water, such as dichloromethane, chloroform, or toluene. After 24 hours of exposure to water, the polymers have gelled and the oil has diffused away leaving behind a transparent, inorganic-organic hybrid shell microcapsule. Addition of inorganic precursors such as TEOS or TIP was investigated for the addition of chemical functionality to the shell. The wide range of sol-gel chemistries and silane-functionalized poly(propylene) glycol monomers available makes the proposed method a powerful route for the preparation of microcapsules with tunable chemical and mechanical properties.

References

- [1] M.K. Reddy et al., *Appl. Biochem. Biotechnol.*, **151** (2008), 565–577.
- [2] Z.Z. Li et al., *J. of Controlled Release*, **111** (2006), 81-88.
- [3] A.S. Utada et al., *Science*, **308** (2005), 537-541.

Figures

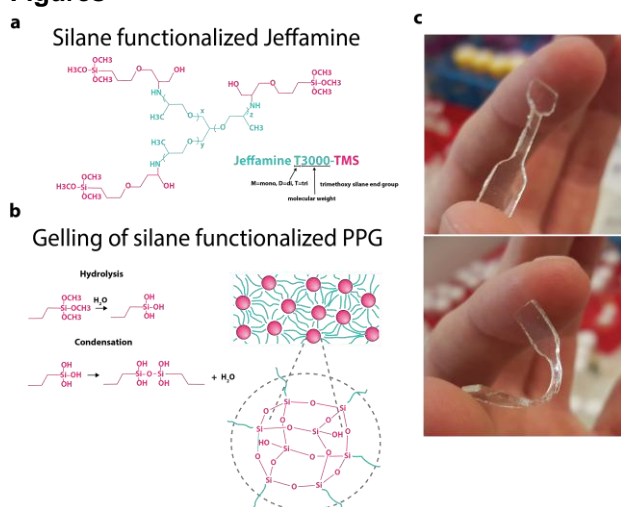


Figure 1. Siloxane-crosslinked poly(propylene glycol) gels produce flexible, optically transparent elastomers. These gels form in the presence of water through a hydrolysis/condensation reaction. a) synthesis of macromonomer, b) gelation reaction, c) a transparent flexible elastomer is formed.