

FLOW INDUCED MECHANOCHEMICAL ACTIVATION

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Conventional polymers undergo chain degradation through bond scission when subjected to high stresses. Materials that adapt their properties or alter their form in response to a change in their environment are known as stimuli-responsive materials. Polymers that productively utilize mechanical energy to initiate chemical reactions prior to bond scission would be potentially useful for enhancing lifetime or detecting damage. For example, self-reinforcing polymers could be realized if cross-linking reactions are induced in the vicinity of a high stress concentration. As another example, a fluorescence unit generated by a stress-induced reaction would signal that a self-assessing polymer was loaded above a threshold value. Recently, structural polymers with the ability to autonomically heal cracks has been developed at the University of Illinois [1]. In the design of self-assessing and self-reinforcing polymers, we now seek to apply this self-healing concept at the molecular level via mechanochemical triggering. By incorporating mechanochemical linking groups in high molecular weight polymer chains we are aiming at a stress-induced reaction that is coupled directly and tailored to the mechanical field. Mechanochemical reactions can then be used to trigger other functions, e.g. fluorescence, healing, repair, toughening, etc.

The most common example of stress-induced reactions in polymers is homolytic bond scission. Staudinger was the first to recognize the possibility of flow-induced destruction of chain molecules [2]. Odell and Keller showed that dilute solutions of high molecular weight macromolecules in extensional flow fields undergo chain extension above a critical strain rate [3]. Various methods have been used to create extensional flow fields, including opposed jets, cross-slots and rotating rollers. The apparatus used in this work is based on opposed jets, where two glass tubes are immersed in solution and aligned facing each other. A stagnation point is created in the center of the flow-cell by extracting fluid through both tubes simultaneously. The stagnation point provides a sufficiently long residency time for the chains to become nearly fully stretched. The coil-to-stretch transformation can be monitored by an optical rheometer based on the flow birefringence resulting from the corresponding molecular orientation in the almost ideal uniaxial flow field.

The focus of this presentation is an experimental method for systematic studies of stress-activated reactions using probe macromolecules and elongational flow fields in an extensional flow-cell. A Senarmont compensator is used for registration of the molecular chain extension and the rheo-optical response of various polymeric solutions is analyzed.

References

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