

Abstract

Self-propelled motion through an internalized chemical reaction, a characteristic of living systems, has led to the design of various synthetic materials that can mimic biological systems. Such synthetic materials work as a motor and convert chemical energy produced from a chemical reaction into mechanical motion. The mechanical motion is generated when the reaction products are distributed asymmetrically in the surroundings of the synthetic system. In this thesis, we have designed a synthetic self-moving macroscopic system through careful use of self-oscillating chemical reaction inside a polymeric gel. We have synthesized spherical beads of PNIPAAm following the free radical mechanism using the alginate technique and used it as a small-scale reactor. Self-sustained motion in the polymer bead is generated by utilizing the chemical energy of the Belousov-Zhabotinsky (BZ) reaction. BZ reaction is an aqueous phase non-linear redox reaction where the transition metal complex acts as a catalyst and oscillates between an oxidized state and a reduced state due to a regulatory feedback mechanism.

In our experiments, the gel beads are soaked with BZ reagents and kept in an oil medium containing a surfactant. Due to the high porosity of the gel beads, the intermediates of the BZ reaction ooze out of the polymer bead and react with the surfactant medium. The interfacial reaction generates a gradient in surface tension, which produces a spontaneous motion of the bead in the oil medium via Marangoni effect. The motion of the bead is controlled by the concentration of the BZ reaction intermediate available for the interfacial reaction. Using a fluorescence microscope, we have recorded the motion of the polymer bead, and observed that the velocity profile of the polymer bead shows an oscillatory behavior because of the oscillation of the intermediate concentration in the BZ medium. We have also observed a significant change in the size of the polymer bead because of the acidic nature of the BZ medium. We further demonstrate that the velocity of the beads can be enhanced by tuning the kinetics of the BZ reaction by the use of graphene nanocomposites. In particular, we show that the use of Ru-graphene nanocomposites as BZ catalysts not only enhances the velocity but also provides directionality in the motion of the polymer beads.

BZ reaction can also produce mechanical oscillations in a polymeric gel system when the transition metal catalyst is covalently attached to the polymer gel. Such polymer gels are called BZ gels as they are capable of undergoing the BZ reaction. The covalent attachment of the transition metal catalyst is possible when a suitable functional group is present on the catalyst

structure. In this thesis, we also propose a methodology to synthesize a bipyridine compound which has been modified with a suitable functional group that can attach the transition metal complex to a polymeric gel system. Specifically, the conversion of the precursor material into a suitable functional group has been done through a series of steps. In the first step, the methyl group in the bipyridine compound is converted into a methoxyethyl group which is then converted into a vinyl group. The modified bipyridine compound is then attached to the BZ catalyst where the vinyl group provides a suitable functional group for the covalent attachment of the BZ catalyst with the polymer gel.