Stimuli-responsive hydrogels are attractive as components of microfluidic device because the swelling response of hydrogel systems is typically diffusion limited, and thus hydrogels at small scales are more efficient. In addition, hydrogels are easy to fabricate in microfluidic device and eliminate the need of integrated electronics, controls, and power source that are required for active components. Here, we demonstrate the concept of using external stimuli to actuate temperature-responsive hydrogel valves. Externally actuated valves are attractive for applications like pulsatile drug release from implanted device, where the dose can be varied easily by variation of external stimuli.

Previously, we have developed magnetic nanocomposites of temperature responsive poly (N-isopropylacrylamide) hydrogels by addition of superparamagnetic Fe_3O_4 particles. The composites respond to alternating magnetic field (AMF) and have been demonstrated for matrix type of externally actuated pulsatile drug release systems. The rate of hydrogel collapse and recovery are key parameters in design of hydrogel as a valve. In this study, the systems were characterized for remote heating on application of AMF and AMF triggered collapse. The effect of AMF was characterized for different particle loadings and different nanocomposite film thickness. Heat and mass transfer analysis was conducted to correlate the film thickness with kinetics of AMF triggered heating, collapse, and subsequent recovery. The gels with higher thickness collapsed faster because heat transfer dominates the collapse. On the contrary, gels with higher thickness recovered slower because mass transfer dominates the recovery process. A simple model was proposed that explains and predicts the collapse and recovery process with hydrogel thickness.

In this study, NIPAAm based hydrogel composites were incorporated as valves in a ceramic microdevice. Flow of room temperature water resulted into hydrogel swelling and the valve closed. The valve was demonstrated for ON-OFF flow control with variation in temperature using a hot plate. The characterization of time needed for valve to open/close was also conducted with a pressure sensor. The goal of this study was also to look at remote actuation capabilities of this valve. Application of AMF to the device selectively heated the valve and resultant temperatures were imaged by an IR camera. As the temperature of matrix increased above the lower critical solution temperature (LCST), the hydrogel collapsed, and opened the valve. This process showed very good reproducibility for multiple ON-OFF cycles. Hence, hydrogel nanocomposites were demonstrated as remote controlled valves.