Tata Institute of Fundamental Research
Survey No. 36/P, Gopanpally Village, Serilingampally, Ranga Reddy Dist., Hyderabad – 500 046

Webinar

Systems Chemistry Approaches for Biomimetics and Material Design

Indrajit Maity

Johannes Gutenberg University of Mainz, Germany

Keeping in mind that life is an out-of-equilibrium process; the study of chemical networks and how they behave under far from equilibrium conditions is interesting and may bring us closer to mimic living systems. Non-linear phenomena, such as oscillation and bistability can be originated from self-replicating networks far from equilibrium. In this context, cellular memory accompanying with such non-linear phenomena by which cells convert a transient signal into a sustained response. The important feature of memory circuits is bistable - they exist in one of two states. Our system comprises of a positive feedback (offering from self-replication process) in a non-symmetric reversible coiled coil peptide network, leading to bistability with two steady states (SS) depending on inputs. Interestingly, these two signalling states are inter-switchable and present a memory like apparatus. Moreover, transduction of signals demonstrating the conversion of one types of signal into other type is achieved by our tractable pathway modification approach while keeping constant the overall mass and energy of network reaction system. In the next level, we have then combined together two fundamentally different reaction systems, namely a peptide-based bistable replication network, and a set of nanoparticle formation reaction and growth (NRG) processes. The success of this assay relies on a cascade pathway, in which the outputs of the bistable network serve as input signals for the consecutive NRG processes, which in turn, depending on the applied experimental configuration and reaction conditions, regulate various features of Au nanoparticle (NP) shape and assembly. To understand such feedback reaction networks in more details, we examine the simple urea-urease or more complex urea-urease/ester-esterase chemical reaction networks confined in hydrogel beads. The real time growth of the basic pH front from the localized reaction network in the alginate bead helps to understand the fundamental modules of feedback-controlled reaction networks (+ and – feedbacks) and other emerging non-linear response (e.g. damping of signals). We diversify the behaviour of such active beads and demonstrate signal-gating shells and chemo-structural feedback. In a systems approach, we encapsulate two antagonistic networks (urea-urease and ester-esterase) separately into different hydrogel spheres to devise communication, pattern formation and attraction by chemotaxis of bead landscapes. Importantly, we also shed light on how the basic pH front can autonomously develop hydrogel materials as well as, guide to construct various 2 and 2.5 D gel structures as well as multi-layered geometric hydrogel shapes although the supramolecular hydrogel is non-injectable in nature and hitherto fails to print using conventional 3D printing tools.

Thus, such processes in non-living chemical systems can describe two important goals. First, it allows us to correlate the synthetic model circuit with the living biological cellular networks and machinery operating far from equilibrium condition. Second, from the nanotechnology and material science standpoint, it upgrades us into a new era in designing (nano) materials depending on pre-encoded molecular programming from feedback reaction network. Thus, we believe that bridging the fields of systems chemistry with material science can expand the possibilities to design new functional materials.

Wednesday, May 19th 2021

4:00 PM