ABSTRACT

Intelligent artificial robots are designed and developed to accomplish routine activities of daily human life. They are envisioned to alleviate the human work load, which are mainly repetitive in nature, in the diverse areas such as cleaning, washing, managing, communicating, computing, and treatment, in order to improve the quality of human life and their expectancy. The robots are also tipped to be employed for advanced technological events such as high-precision sensing, interaction with humans, operations of aircrafts or artilleries, energy harvesting, and environmental remediation. Interestingly, robot manufacturing is often inspired from the various living objects present in the nature, such as humans, plants, extra-terrestrial elements, animals, insects, bacteria, viruses, and parasites, among others. The present era has witnessed the use of robots having different length scales ranging from a few meters to the level of a few nanometers targeting different applications. For example, a collection of macroscopic swarm 'kilobots' with programmable controllers and locomotive capacity can show collective artificial intelligence such as sync, transport, assembly to realize routine jobs. On the other hand, self-propelling micro or nanoscopic robots, also popularly known as micro or nanobots, find important futuristic applications in the domains of targeted drug delivery, payload transport, therapeutics, diagnostics, imaging, and high precision sensing, among others.

In this regard, the fabrication of the micro or nanoscale robots undergoing controlled migration is one of the very challenging fields of research. Largely, the micro or nanomotors can be classified into hard-non-deformable and soft-deformable types. The non-deformable micro or nanomotors are mechanically tough and in general composed of metals or metal-alloy, hard polymers, piezoelectric or other smart materials with higher elastic modulus. In contrast, the soft micro or nanobots is capable of changing their shape during migration and are composed of liquid droplets or soft-viscoelastic polymers or hydrogels with relatively smaller elastic rigidity. Interestingly, the motions of the soft or hard mesoscale self-propelling objects are very often controlled by different *in situ* or remote guidance such as chemical potential, photonic excitation, electromagnetic field, acoustic waves, and thermal energy, among others. An extensive literature survey suggested that there are many areas, which require immediate attention for a rapid progress of the design and development of commercial micro or nanobots. This include, (i) design and development biocompatible 'superbots' – micro or nanobots capable of self-propulsion through

multiple external stimuli such as chemical potential, electric or magnetic fields; (ii) use of soft and hard materials to design and develop superbots undergoing chemotaxis, galvanotaxis, or magnetotaxis; (iii) study the effects of the fluid properties on the different motions of the microbots; (iv) develop theoretical and computational models to explain the various features of their movement; (v) apply the self-propelling motions of the soft and hard motors for payload transport, drug delivery, or emulsification; (vi) improve the fundamental understanding of the response of a soft or hard motor in presence of chemical, electric or magnetic stimuli.

In view of the above, the present thesis reports the design and development of a host of biocompatible soft and hard microbots composed of graphene coated on glass microbeads, metal nanoparticles coated on glass microbeads, oil or water droplets. These microbots are capable of showing controlled motion under the influence of either *in situ* chemical potential gradient or externally applied electric or magnetic field. While the hard 'superbot' composed of graphene coated glass bead have shown chemotaxis and galvanotaxis under the influence of *in situ* chemical potential gradient and externally applied electric field, deposition of a trace of iron nanoparticles on the surface of this motor infuses the capacity to move under magnetic field to demonstrate magnetotaxis. Further, the soft 'liquibots' such as the 'waterbot' and the 'oilbot' have been prepared infusing paramagnetic and diamagnetic salts into the water or the oil droplets. The salt laden oilbots and waterbots showed curious push and pull magnetotactic motility under the remote magnetic guidance. Fascinatingly, under the sole influence of electric field, oil droplets on a continuous water bath have shown interesting galvanotactic locomotion such as oscillation, spreading or ejection while under Lorenz force the same system showed clockwise and counter clockwise rotational locomotion. In addition, a droplet breaking mechanism under a chemical stimulus has been uncovered, which is capable of generating a microemulsion from a macroscopic water droplet in a single step process. In such a scenario, the droplet shows interesting spreading and dewetting of the macroscopic droplet before forming metastable fluidic structures such as toroid, liquid sheet, or high aspect ratio liquid thread, among others. The aforementioned prototypes and their response to the external stimulus can be employed for a number of futuristic applications. For example, (i) the graphene coated glass microbots can perform payload transport, drug delivery or as a stent for cleaning of blood vessels, (ii) the water or oilbots can be employed for drug delivery applications, (iii) the rotating or oscillating incompressible droplets can be employed for pumping applications inside the microfluidic devices, (iv) the chemical stimuli induced droplet breakup can be employed as a single step methodology to form micro or nanoemulsion, (v) the droplet breakup experiments can be employed to synthesize miniaturized droplets with very high surface-to-volume ratio.