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Multifunctional Janus Microbots for Intracellular Delivery of Therapeutic Agents

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Abstract : Unlike traditional robots, medical microbots are not only smaller in size, but they also possess various unique properties, for example, biocompatibility, stability in the biological fluids, navigation opposite to the bloodstream, wireless control over locomotion, etc. The idea behind their usage in the medical field was to build a minimally invasive method for addressing the post-operative complications, including longer recovery time, infection eruption and pain. Herein, the present study demonstrates the fabrication of dual nature magneto-conducting Fe3O4 magnetic nanoparticles (MNPs) and SU8 derived carbon-based Janus microbots for the efficient intracellular delivery of biomolecules. The low aspect ratio with feature size 2-5 µm microbots were fabricated by using a photolithography technique. These microbots were pyrolyzed at 900°C, which converts SU8 into amorphous carbon. The pyrolyzed microbots have dual properties, i.e., the half part is magneto-conducting and another half is only conducting for sufficing the therapeutic payloads efficiently with the application of external electric/magnetic field stimulations. For the efficient intracellular delivery of the microbots, the size and aspect ratio plays a significant role. However, on a smaller scale, the proper control over movement is difficult to achieve. The dual nature of Janus microbots allowed to control its maneuverability in the complex fluids using external electric as well as the magnetic field. Interestingly, Janus microbots move faster with the application of an external electric field (44 µm/s) as compared to the magnetic field (18 µm/s) application. Furthermore, these Janus microbots exhibit auto-fluorescence behavior that will help to track their pathway during navigation. Typically, the use of MNPs in the microdevices enhances the tendency to agglomerate. However, the incorporation of Fe_3O_4 MNPs in the pyrolyzed carbon reduces the chances of agglomeration of the microbots. The biocompatibility of the medical microbots, which is the essential property of any biosystems, was determined in vitro using HeLa cells. The microbots were found to compatible with HeLa cells. Additionally, the intracellular uptake of microbots was higher in the presence of an external electric field as compared to without electric field stimulation. In summary, the cytocompatible Janus microbots were fabricated successfully. They are stable in the biological fluids, wireless controllable navigation with the help of a few Guess external magnetic fields, their movement can be tracked because of autofluorescence behavior, they are less susceptible to agglomeration and higher cellular uptake could be achieved with the application of the external electric field. Thus, these carriers could offer a versatile platform to suffice the therapeutic payloads under wireless actuation.

Keywords : amorphous carbon, electric/magnetic stimulations, Janus microbots, magnetic nanoparticles, minimally invasive procedures
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