J Biosens Bioelectron 2017, 8:2(Suppl)
DOI: 10.4172/2155-6210-C1-034

Microfluidic droplets and their applications

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Droplets of nanoliter and subnanoliter are useful in a wide range of applications, particularly when their size is uniform and controllable. Examples include biochemistry, biomedical engineering, food industry, pharmaceuticals, and material sciences. One example of their many fundamental medical applications is the therapeutic delivery system for delivering site-specific therapy to targeted organs in the body and as the carriers for newer therapeutic options. The size, the size distribution, the generation rate and the effective manipulation of droplets at a scale of nano, pico, femto and even atto liters are critical in all these applications. We make an overview of microfluidic droplet generation of either passive or active means and report a glass capillary microfluidic system for synthesizing precisely controlled monodisperse multiple emulsions and their applications in engineering materials, nanofluids, microfibers, embolic particles and colloidosome systems. Our review of passive approaches focuses on the characteristics and mechanisms of breakup modes of droplet generation occurring in microfluidic cross-flow, co-flow, flow-focusing, and step emulsification configurations. The review of active approaches covers the state-of-the-art techniques employing either external forces from electrical, magnetic and centrifugal fields or methods of modifying intrinsic properties of flows or fluids such as velocity, viscosity, interfacial tension, channel wettability, and fluid density, with a focus on their implementations and actuation mechanisms. Also included is the contrast among different approaches of either passive or active nature.

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Self-assembled polymeric nanoparticles as new, smart contrast agents for cancer early detection using magnetic resonance imaging

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Early cancer detection is a major factor in the reduction of mortality and cancer management cost, the development of new tools for this purpose is of great value. Since healthy and pathological tissues as well as distinct diseases show similar magnetic moments, they produce a poor image contrast. In order to get a better anatomical differentiation and improve sensitivity, contrast agents (CAs) are used. Here, we present the development of a smart and targeted polymeric nanoparticle-based contrast agent (CA) for magnetic resonance imaging, able to turn on its imaging capability in the presence of target cancer cells. The new CA consists of pH-sensitive polymeric micelles formed by self-assembly of a diblock copolymer (PEG-b-PTMSMA), loaded with a gadolinium (III) complex (^{t}BuBipyGd) and explores the acidic pH in cancer tissues. *In vitro* and *in vivo* experiments have shown that the designed nanoparticles are indeed pH-sensitive, in that they remained intact in neutral pH and turned on its imaging ability upon disruption in an acidic microenvironment. This encapsulation procedure significantly reduced the ^{t}BuBipyGd complex cytotoxicity towards Jurkat and MCF-7 cell lines. The targeting ability of nanoparticles towards cancer cells was enhanced by conjugation with the C595 monoclonal antibody against the human MUC1 protein, which is often overexpressed in breast cancer. Indeed, nanoparticle uptake by MUC1-expressing cells was higher for targeted than for non-targeted micelles. In addition, the uptake of targeted micelles by MUC1-expressing cells was stronger than by MUC1-negative cells.

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