Particles and molecules: controlled interaction and on-demand release

Background. Our research is focused on the interaction of particles with the surrounding environment that affects practically relevant properties of that environment. The ability of particles to release their drug load when and where necessary affects functioning of the nearby cancer cells or bacteria. Interference of particles with the chemical communication of cells allows for the control of their collective behavior, such as biofilm growth or susceptibility to a viral infection. Similar effects can be achieved by mimicking of cells or viruses with properly functionalized particles.

Research Approach. *1) Targeting metastatic colorectal cancer by targeted release drug delivery nanoassemblies.* We load mesoporous nanoparticles based on silica and hydroxyapatite with an anti-cancer veratridine and seal it inside with casein. Due to their surface charge, the blood-brain-barrier-impermeable particles have selective affinity to cancerous cells. In the tumor tissue, the casein is digested by the MMP-7 protease and acid overexpressed by the cancerous cells, which releases veratridine at the target.[1]

2) Repurposing of tooth desensitizing particles for the on-demand oral drug delivery. Tooth hypersensitivity is known to be treated by the occlusion of the dentinal tubules exposed to the oral cavity.[2] We found that a range of nontoxic particles are able to occlude dentinal tubules in an aqueous suspension,[3] can be attached to the engineered surface dental floss[4] and assist in the tooth remineralization.[5] We explore ability of these particles to carry antibacterial eugenol or other drugs and release them at the bacteria-affected areas of the tooth known for their elevated acidity in vitro mimicking the human tooth in a newly developed microfluidic device.[6]

3) Control of the biofilm growth by engineered 2D-carbons. We found that functionalized graphite microparticles prepared by mechanoactivated exfoliative Diels-Alder addition to graphite[7] inhibit bacterial growth[8] and modify monolayer graphene by p-p stacking. We are exploring the ability of the modified graphite microparticles to carry quorum sensing agents able to control the formation of biofilms on 2D-surfaces.

4) Nontoxic biodegradable carriers for genetic modification of plants. Our laboratory has engineered modified nontoxic biodegradable hydroxyapatite nanorods able to carry DNA to the plant cells.[9] This nanocarrier is superior to more commonly used carbon nanotubes, which persist in the environment and may cause unintended genetic transfection. We are exploring the potential of our new particles to carry gene editing systems inside the cells and develop commercializable methods for agriculture.[10]

5) Mimicking viral surfaces by nanoparticles to evaluate vaccines and antiviral compounds. We study the role of surface molecules on the functioning of the immune system and antiviral drugs, mimicking viruses by similarly sized and shaped fluorescent silica nanoparticles. For instance, covalent attachment of H1N3 antigens to the particles enabled us to rapidly assess concentration of antiviral antibodies and therefore evaluate quality of vaccines.[11-12] Now we are exploring the role of surface human agglutinins on the suppression of the viral replication.

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