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EDITORIAL

Nanomaterials for biomedical imaging and targeting

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Nanotechnology has an enormous impact on the modern technology and everyday life. A plethora of novel effects arise from the downsizing of materials. Particularly, the high surface area to volume ratio of nanomaterials combined with many other unique properties such as tunable optical and magnetic properties, possibility of targeted delivery, and specific binding via surface functionalization made nanomaterials appropriate tools for biomedical applications. Together with recent advances in the synthesis and engineering, various nanoparticles (NP) are very promising tools for non-invasive visualization of cellular objects, functions, and processes in living subjects. Molecular imaging with use of NPs has an obvious potential in accurate diagnosis and prognosis of diseases such as cancer or Alzheimer's disease at early stages.

The topical collection "Nanomaterials for biomedical imaging and targeting" highlights the rapidly expanding uses and interest in nanomaterials for bioapplications such as imaging, sensing, and targeting. In total, one review and nine research articles with focus on this scientific area were selected. In the following, we would like to provide a brief overview of the contributions, which are accessible via https://link.springer.com/collections/giiacgbfhb.

The review prepared by Belza et al. covered basic physico-chemical characteristics of carbon dots (CD) and summarized current options of virus detection utilizing CDs by either electrochemical or optical sensing approaches. The authors shared the up-to-date knowledge of CDs' antiviral properties and the mechanisms of their antiviral actions. Advantages and disadvantages of CDs against viral infection were discussed to provide valuable information for both new detection methods and antiviral therapeutics.

The following research articles focused not only on simple imaging using mostly fluorescent NPs but provided also examples of intracellular sensing of specific markers.

Shang et al. introduced a sensitive fluorescence nanoprobe based on FRET mechanism for detection of hydrogen peroxide. The probe combined core–shell Ag@Au NPs as a fluorescence receptor and red emissive graphene quantum dots (QD) as a donor. Through π stacking between the DNA strands bound to the Ag@Au NPs and the graphene QDs, the resulting conjugate formed a satellite structured nanoprobe. Attributing to the synergistic effect of red emission, efficient FRET, and effective DNA cleavage, the nanoprobe exhibited high detection sensitivity towards hydrogen peroxide. A negligible cytotoxicity and effective accumulation in tumor cells helped to realize monitoring and imaging of hydrogen peroxide inside living cells.

Verdin et al. demonstrated quantitative surface enhanced Raman spectroscopic (SERS) imaging on tissues using Au@Ag NPs protected by a polymer shell and functionalized with monoclonal antibodies (mAb) against human epidermal growth factor receptor 2 (HER2). The PEG coating drastically reduced non-specific interactions with tissues, while the mAbs allowed a highly specific targeting of HER2. The designed SERS nanoprobes were combined with a spectral imaging and data weighting procedure to demonstrate correlation of the SERS signal with the amount of HER2 antigen on the cell membranes. In this way, information on significantly different expression levels of HER2 at several microscopic tumor parts of the imaged tissue slice was acquired.

Ding et al. introduced a Au NP-based probe for NF-κB transcription factor detection and in situ imaging via steric hindrance. The probe contained Au NPs to quench fluorescence of Cy5 labeled nucleic acids immobilized on the NPs. In the basal state, DNA1 folded into a hairpin structure, the Cy5 fluorophore approached close to the surface of Au NPs

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acting as a quencher. Inside the cell, the present NF-κB transcription factor bound to the κB site in the DNA duplex and the steric hindrance caused extension of the long chain of DNA1; the Cy5 fluorophore was released from the surface of NPs, thereby restoring its fluorescence. The method was able to distinguish between active NF-κB (nucleus) and inactive NF-κB (cytoplasm) through in situ sub-localization.

Mahani et al. synthesized carbon QDs with intense fluorescence emission ($\lambda_{ex} = 370$ nm, $\lambda_{em} = 450$ nm). These QDs imprinted with N-acetylneuraminic and glucuronic acids were successfully applied to targeting and imaging of HepG-2 (human hepatoma carcinoma cells) and MCF-7 (human breast cancer cells). NIH-3T3 normal mouse embryonic fibroblast cells were used as a control. These monosaccharide-imprinted polymers were capable to selectively target the tumor cells in the presence of normal ones.

Zhou et al. reported design and construction of lysosome-targetable selenium-doped carbon nanodots (Lyso-Se-CD) that can significantly diminish lysosomal hydroxyl radicals in living cells and mice. The Lyso-Se-CDs with redox-responsive fluorescence ($\lambda_{ex} = 379$ nm, $\lambda_{em} = 471$ nm) exhibited excellent colloidal stability, robust scavenging of hydroxyl radicals, low biotoxicity, and good biocompatibility and specific targeting of lysosomes. Thanks to these advantages, the Lyso-Se-CDs protected cells from elevated lysosomal levels of hydroxyl radicals. More importantly, the Lyso-Se-CDs efficiently relieved phorbol 12-myristate 13-acetate triggered ear inflammation in live mice.

Zheng et al. described a biomimetic recognition strategy for capture and release of tumor cells. The gold-coated magnetic nanomaterials were modified with DNA primers to form long DNA products by the rolling circle amplification to resemble jellyfish tentacles. They contained multivalent aptamers extending in all directions and thus increasing the accessibility and specific capture of the target cells. The capture efficiencies were up to 92% and 77% in buffer and blood, respectively. Subsequently, DNase I degraded the biomimetic tentacles and released the captured cells with high viability.

Zhang et al. synthesized nitrogen-doped carbon dots (N-CD) by the one-step hydrothermal carbonization method. The NPs possessed small size, bright and stable green fluorescence, abundant surface functional groups, and good biocompatibility. The N-CDs bound to RNA in nucleoli to enhance the fluorescence, which ensured nucleolus-orientation imaging of HeLa and PC12 cells with highly specific and simplified wash-free procedure, suitable for biomedical analysis and clinical diagnostics.

He et al. reported a new nanoplatform based on glutathione-responsive mesoporous silica NPs for cancer therapy and mitochondrial imaging. The system consisted of Au NPs, mesoporous silica NPs, cationic ligand, doxorubicin, and CDs. Since Au NPs were etched by the intracellular glutathione (GSH) via ligand exchange induced etching process, doxorubicin was released into the cells in a GSH-dependent manner which results in the superior GSH-modulated tumor inhibition activity. Moreover, after etching by GSH, the nanoplatform served as promising fluorescent probe ($\lambda_{ex} = 633$ nm, $\lambda_{em} = 650$ nm) for targeted imaging of mitochondria in living cells with near-infrared fluorescence. The authors proposed that the anti-cancer mechanism of the system occurs via an induction of apoptosis initiated by depolarization of the mitochondrial membrane.

Finally, Pořízka et al. introduced laser-induced breakdown spectroscopy (LIBS) for specific determination of breast cancer biomarker HER2 within tissues and cell cultures. The streptavidin-conjugated upconversion NPs were used to label cell pellets through a primary anti-HER2 antibody and a biotinylated secondary antibody. The LIBS scanning enabled detecting the characteristic elemental signature of yttrium as a principal constituent of the upconversion NPs, thus indirectly providing a reliable way to differentiate between HER2-positive cells and negative cells. LIBS seems to be a promising alternative readout to the widely used immunohistochemistry and immunocytochemistry approaches.

Overall, the articles selected for this topical collection offer new insights into interesting developments in the emerging field of biomedical imaging and targeting using various types of nanomaterials, different application procedures, targeting mechanisms, and signal acquisition techniques. We are grateful to all the authors who contributed to this collection and express our acknowledgments to the referees for careful reviewing of the submitted manuscripts.

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Declarations

Conflict of interest The authors declare no competing interests.