Editorial

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Nanotechnology, photonics, and immunotherapy for cancer diagnostics and therapeutics

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Nanomaterials have marked a revolutionary milestone in the development and applications of new technologies in the biomedical fields. At the core, bionanotechnology, particularly design and applications of nanoplatforms, is interdisciplinary in nature, encompassing research areas of biology, chemistry, engineering, and medicine. When combined with photonics, nanomaterials have significantly enhanced photothermal, photochemical, and photoimmunological interactions for cancer diagnosis and treatment. Cancer Immunotherapy has recently been accepted as a main-stream therapy, epitomized by two milestones: being named by the journal *Science* as the “Breakthrough of the Year” in 2013 and being recognized by the *2018 Nobel Prize in Physiology or Medicine* for the “discovery of cancer therapy by inhibition of negative immune regulation”. The combination of nanotechnology, biophotonics, and immunotherapy presents an exciting and promising approach for cancer diagnosis and treatment. This Special Issue aims at bringing more attention of researchers, clinicians, and other healthcare providers to this field.

Photoresponsive nanomaterials have shown promising outcomes for cancer theranostics due to their unique optical properties. Jain et al. [1] reviewed the recent developments of photo-activated nanomaterials as cancer theranostics agents; they discussed in detail the applications of various light activated nanohybrid agents for multimodal imaging and synergistic phototherapy. Persistent luminescence materials continue emitting light long after excitation stopped and it could be used to overcome the limitations of photodynamic therapy (PDT) concerning deep-seated targets. The review by Bessière et al. [2] focused on the applications of persistent luminescence materials for multimodal imaging and therapy. The surface plasmonic platform with spin Hall effect of light is expected to be applied for integrated optical devices. Yu et al. [3] reviewed the recent progress on the spin Hall effect of light based on the plasmonic platform.

More and more nanomaterials have been designed for cancer phototherapy. Liang et al. [4] combined benzoporphyrin derivative and the conformational-sensitive UIC2 monoclonal antibody to target active human ABCB1, which overexpressed on triple negative breast cancer cells. Saha et al. [5] reported two novel nanoparticles for targeting drug resistance in the model of breast cancer: lipid-drug conjugates that target molecular signaling pathway and gold nanorods carrying activated vehicles that release payloads after light illumination. Hernández et al. [6] described the *in vitro* study of a nanobody-photosensitizer conjugate targeting epidermal growth factor receptor to treat feline oral squamous cell carcinoma in the veterinary clinic. Dhaini et al. [7] reviewed research using nanoparticles coupled or loaded with photosensitizers and grafted to peptides for targeted PDT. Wakiyama et al. [8] reviewed clinical applications of near infrared photoimmunotherapy that uses monoclonal antibody coupled photoactivatable phthalocyanine-derivative dye. Rodríguez et al. [9] produced new structures of welded gold rod-spheres under femtosecond laser pulse irradiation for surface-enhanced spectroscopies or plasmonic photothermal therapy (PTT). Guidolin et al. [10] showed that porphyrin-lipid nanovesicles, referred to as porphysomes, are effective photosensitizers for PDT of athymic nude mice bearing subcutaneous A549 human lung tumors. Guirguis et al. [11] reported that

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membrane composition of NIR-activable liposomes can significantly enhance phototriggered burst release of entrapped, fluorescence intensity, and cancer cell phototoxicity.

Immunomodulation therapy has seen an explosion in interest recently. Various studies of immunomodulation are also discussed in this Special Issue. Yokomizo et al. [12] reported the adjuvant effect of NIR-laser augmentation of early antibody responses to intradermal influenza vaccination in mice, with CD103⁺ dendritic cells playing a critical role of the process. Silva et al. [13] reported that triple-receptor-targeted (EGFR, Tfr, HER-2) photoimmuno-nanoconjugates mediated photodynamic priming, which induced light dose-dependent phototoxicity and T cell-mediated immune responses in treating pancreatic ductal adenocarcinoma in murine models. Glushkovskaya et al. [14] determined 1267 nm laser can stimulate lymphatic delivery to the brain and glioma of liposomes, bypassing the blood brain barrier.

This Special Issue also presents the combination of nano-based phototherapy with other therapies. Zou et al. [15] summarized the recent advances in the development of phototherapy triggered immunotherapy for cancer treatment. Hoover et al. [16] reviewed the applications and limitations of nanoablative immunotherapy, particularly with the combination of immune checkpoint therapy; they also proposed potential strategies to overcome the immunosuppressive tumor microenvironment (TME) using the nano-photo-immuno approaches. Liu et al. [17] reported that the combination of Fe₂P nanorods modified with DSPE-PEG₂₀₀₀-Mal and programmed death ligand 1 (PD-L1) antibody could elicit phototherapeutic effect and strengthen immunological response for primary tumor ablation and metastasis control. Lou et al. [18] developed porphyrin lipoproteins as a new type of photosensitizer for PDT, which could effectively induce immune response and, when combining with programmed death 1 antibody, could prolong survival time. Liu et al. [19] investigated the effect of gold nanostars-mediated PTT in eliminating primary tumors and reversing immunosuppressive TME, by combining with checkpoint blockade to improve the control of remote and unresectable cancer metastases. Deinaizadeh et al. [20] designed a mesoporous silica particle loaded with doxorubicin (DOX) and gold nanorods, presenting the combination of tumoricidal effects of PTT and chemotherapy on human lung cancer cells. Liu et al. [21] developed a polydopamine nanoparticle loaded with DOX and Curcumin, which achieved immunostimulatory photochemotherapy for the treatment of colon tumors, successfully resisting tumor rechallenge.

Large amounts of studies also have exploited for photo diagnosis and imaging-guided phototherapy. In this Special Issue, Zhu et al. [22] presented magnetic black phosphorus microbubbles to improve tumor targeting under magnetic field, which achieved enhanced effect of ultrasound imaging guided PTT for breast cancer. Wang et al. [23] developed a wavelength-switchable photoacoustic microscopy for high-resolution visualization of tumor microvasculature and accurate localization of nanoparticles to guide PTT and evaluate phototherapeutic effectiveness simultaneously. Deng et al. [24] developed a drawer-type abdominal window with an acrylic/resin coverslip for long-term *in vivo* fluorescence/photoacoustic imaging of self-assembled pomegranate structure-like nanoparticle labeled Kupffer cells and GFP labeled natural killer T cells, which not only overcame the breathing and heartbeat jitters but also balanced the penetrability of light and acoustic signals.

This Special Issue focuses on the synergistic applications of nanophotonics (nanotechnology and photonics), and immunology. We extend our gratitude to all contributing authors and welcome more contributions on the fundamental science and applications in this research area.

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