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Upconversion Nanomaterials for Applications in Life Sciences and Medicine

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Abstract : Light has proven to be useful in a wide range of biomedical applications such as fluorescence imaging, photoacoustic imaging, optogenetics, photodynamic therapy, photothermal therapy, and light controlled drug/gene delivery. Taking photodynamic therapy (PDT) as an example, PDT has been proven clinically effective in early lung cancer, bladder cancer, head, and neck cancer and is the primary treatment for skin cancer as well. However, clinical use of PDT is severely constrained by the low penetration depth of visible light through thick tissue, limiting its use to target regions only a few millimeters deep. One way to enhance the range is to use invisible near-infrared (NIR) light within the optical window (700–1100nm) for biological tissues, extending the depth up to 1cm with no observable damage to the intervening tissue. We have demonstrated use of NIR-to-visible upconversion fluorescent nanoparticles (UCNPs), emitting visible fluorescence when excited by a NIR light at 980nm, as a nanotransducer for PDT to convert deep tissue-penetrating NIR light to visible light suitable for activating photosensitizers. The unique optical properties of UCNPs enable the upconversion wavelength to be tuned and matched to the activation absorption wavelength of the photosensitizer. At depths beyond 1cm, however, tissue remains inaccessible to light even within the NIR window, and this critical depth limitation renders existing phototherapy ineffective against most deep-seated cancers. We have demonstrated some new treatment modalities for deep-seated cancers based on UCNP hydrogel implants and miniaturized, wirelessly powered optoelectronic devices for light delivery to deep tissues.

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