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Stable Black Phosphorus/Bi_2O_3 Heterostructures for Synergistic Cancer Radiotherapy

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ABSTRACT

X-ray induced photodynamic therapy (X-ray-PDT) is a promising approach for synergistic cancer radiotherapy and development of suitable radiosensitizers is highly desired. In this paper, we propose black phosphorus/Bi_2O_3 (BP/Bi_2O_3) heterostructures as efficient and biocompatible radiosensitizers for synergistic cancer radiotherapy. The heterostructures are synthesized by growth of ultrasmall Bi_2O_3 nanoparticles onto BP nanosheets. The Bi_2O_3 decoration inhibits the rapid degradation of BP nanosheets by occupation of the defect sites, and the synergistic effects of BP and Bi_2O_3 enable $^1O_2$ overproduction under X-ray irradiation. This X-ray-PDT effect of the BP/Bi_2O_3 nanosheets enhances the radiotherapy activity towards cancer cells by inducing cell apoptosis and cycle arrest. *In vivo* treatment of melanoma conducted on a clinical radiotherapeutic instrument demonstrates that the BP/Bi_2O_3 sensitized radiotherapy inhibits tumor growth efficiently. Furthermore, the BP/ Bi_2O_3 nanosheets composed of biological friendly P, O, and Bi elements shows good biocompatibility *in vitro* and *in vivo*. This radiosensitizer thus has immense clinical potential for cancer therapy, and our findings reveal a general strategy to fabricate stable