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On-demand modulation of drug release using near-infrared-light-responsive plasmonic nanofibrous materials

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On-demand drug-delivery systems based on nanofibers are suitable for controlling the drug release rate at the required moment to achieve the desired therapeutic effects. Electrospun nanofibers with decent drug-loading capabilities, controlled release, and outstanding stability have gained the attention of researchers. Nanofibers for drug delivery applications are categorized according to their morphology, chemical structure, and drug-release mechanism. Using suitable polymers having strong polymer-drug interaction, a high surface-to-volume ratio, and a porous nanofiber mesh is essential for controlled drug release. Besides, using plasmonic nanoparticles can increase opportunities to develop multifunctional activable drug delivery systems. Gold nanoparticles are stimuli-responsive nanomaterials with the inherent capability to produce a light-triggered heat zone. Producing stimuli-responsive nanofibers is a highly intricate process that depends on a wide range of parameters, although there are several methods to fabricate the desired drug-release profiles. To fabricate a light-responsive drug carrier, PVA electrospun nanofibers were loaded with Rhodamine-B (RhB) as a drug model. In the next step, the coaxial electrospinning technique introduced a shelf of PLGA to cover the PVA nanofibers. After the successful fabrication of core-shell nanofibers, further effort was taken to decorate the nanofibers with gold nanorods (Au NRs) simultaneously with electrospinning.

The produced core-shell fibers have smooth and uniform surfaces with no beads running along them. An 810 nm NIR laser was used to irradiate on the system to investigate the plasmonic nanoplatform's photo-responsive behaviour. Due to the presence of gold nanorods, the PVA/PLGA decorated with plasmonic nanoparticles exhibited a strong absorption of the NIR laser and conversion into thermal energy. The system's temperature rose rapidly and significantly, eventually causing the aqueous media around it to escalate. Gold nanorod's ability to efficiently convert incident light into heat energy results in a significant and gradual temperature increase of up to 42 °C upon irradiation. The primary objective of controlling drug delivery is to maximize its release rate to maintain the drug level within a therapeutic window by minimizing drug side effects and focusing on specific tissues and cells.

The pulsatile release of drugs can be adjusted following the requirements of the therapy by using the periodic switching on and off pattern of laser irradiation. The use of stimuli to control drug release provides a system with protection against thermal degradation, which is one of the benefits of our system. The Core-shell structure of the nanofibrous system correspondingly enabled a burst and on-demand drug release from a hydrophilic polymer (PVA) in an aqueous media. We first examined the release at human body temperature to emphasize the effect of laser irradiation on the system's dye release. The cumulative release of the PVA, PLGA, and core-shell system exhibited the effect of the polymer fibre structure on drug release. By irradiating the nanostructured platform decorated by Au NRs with a NIR laser, we could investigate the effects of irradiation on the dye release. The non-irradiated platform release was about 0.1% per hour, and irradiation elevated the release rate to 2% per hour, which confirmed a significant increase in release rate. This elevation demonstrates that the mutual effects of the hierarchically structured nanoplatforms and their interaction with NIR-light may enhance the release rate and ultimately trigger a therapeutic action even at longer experimental times.

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