Photothermal stimulation of neurons by plasmonic nanomaterials promotes neuromodulation and accelerated regeneration of damaged axons

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Accelerated and directed growth of neuronal processes is a necessary condition for successful regeneration of damaged peripheral nerves. Nanofibers with a size of 60-100 nm, imitating the structures of the extracellular matrix, can accelerate the growth of neurites. Photothermal stimulation of nerve cells can additionally initiate accelerated growth, as well as regulate cellular activity, providing a remotely controlled thermal effect. Combining these approaches has made it possible to create "smart" scaffolds to efficiently guide axon and neurite outgrowth. To obtain a biocompatible light-transforming nanomaterial, we used two methods: coating the surface of nanofibers with plasmonic CuS-BSA nanoparticles and incorporating nanoparticles inside the fibers. The efficiency of photothermal heating of the obtained nanomaterials under the action of 808 nm radiation is shown. We have shown photoinduced intracellular heating and release of Ca2+ ions, which confirms that local heat generation on the surface of nanofibers can stimulate neuronal activity. Thermal stimulation of neuroblastoma cells on scaffolds decorated with nanoparticles enhanced the growth of neurites and promoted cell differentiation. Decorating the surface of fibers with nanoparticles leads to strong branching, increase in the number of neurites per cell, and elongation of neurites, especially during photothermal stimulation. The topology of the surface of the composite matrix and the thermally inducing effect of nanoheaters positively affect the growth of axons of the dorsal root ganglia of rats, providing accelerated growth of axons under conditions of hyperglycemia. Thus, photothermal and mechanical (nanotopology of fibers decorated with nanoparticles) stimulation promotes regeneration and growth of DCG axons in a model of metabolic nerve damage. Light-transforming 3D materials open up new possibilities for controlled photothermal neuromodulation as "smart" materials in reconstructive neurosurgery.