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Biologically templated assembly of hybrid semiconducting nanomesh for high performance field effect transistors and sensors

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One-dimensional semiconducting nanomaterials have been extensively investigated for active devices on flexible substrates or sensing devices to amplify weak chemical or biological signals.Network structures produce collective properties out of heterogeneous nanomaterials. Moreover, its percolated electronic paths with a large surface-area allows for efficient interactions with ionic or chemical systems. However, although various approaches have been developed, fabricating well-controlled network structures onto relevant substrates with desired location and dimension still remains a significant challenge. Here we report a highly controllable and non-destructive approach for producing a free-standing large-area semiconducting networkin solution that is readily suitable for semiconducting network-based device integration onto arbitrary substrates. In our approach, semiconducting single-walled carbon nanotubes (SWNTs) were assembled into a network-structured semiconducting layer in solution using a biological template, an M13 phage with strong binding affinity toward SWNTs, to yield a free-standing hybrid semiconducting nanomesh layer in solution.We used the semiconducting nanomesh to successfully fabricate a field-effect transistor (FET) with an Ion/Ioff ratio of ~ 104by employing a simple stencil mask. We further demonstrated that the intact biological functionality resulting from the non-destructive and room-temperature process, the intimate contact between the biological template and the SWNT, and the well-controlled nanostructureof thehybrid semiconducting nanomesh enabled a highly sensitive electrochemical modulation of the FETs. Thehybrid semiconducting nanomesh-based FETs detected a sub-ppb concentration ofthe smallneurotransmitter molecule dopamine in a biologically relevant solution. Our work provides a potentially promising route to realizing a network-structured active layer for high-performance flexible electronics and sensors.

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