Field Effect Transistors Based on Semiconductive Microbially Synthesized Chalcogenide Nanofibers

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While significant attention has been dedicated to understanding the synthesis and structure-function relations of the most abundant biominerals, especially carbonates and phosphates, the last decade has also witnessed additional interest in exploiting microbial strategies for producing a wider range of synthetic nanomaterials with technologically relevant functionalities. Chalcogenide compounds represent an intriguing target for biogenic synthesis. Depending on composition and synthesis techniques, chalcogenide materials may be crystalline or glassy, metallic, semiconductive, or ionic conductors. This versatility leads to a wide range of tunable functionalities in various components including sensors, waveguides, and photoactive devices. Harnessing microbial processes to synthesize such semiconductors in physiological conditions offers advantages over traditional physical and chemical strategies that typically require more extreme environments (temperature, pressure, and pH).

In this study, we present in situ microscopic observations to characterize the microbial synthesis of individual arsenic sulfide (As_xS_y) nanofibers by the dissimilatory metal-reducing *Shewanella* species, and detail the crystallographic, structural, band gap, and electronic properties of the resulting nanofibers. This process relies on the remarkable metabolic versatility of *Shewanella* to concomitantly reduce $S_2O_3^{2-}$ to S^{2-}, serving as a terminal electron acceptor, and As(V) to As(III), thought to occur via As reductases tied to either the respiration or detoxification pathways. In contrast to previous detailed studies of chalcogenide synthesis by *Shewanella* sp. strain HN-41, we focused our attention on *Shewanella oneidensis* MR-1 as well as *Shewanella* sp. strain ANA-3 and mutants of strain ANA-3 deficient in arsenic reduction. The use of strain ANA-3 resulted in significantly more rapid precipitation of As_xS_y nanofibers than previously reported, under identical conditions. Furthermore, we demonstrate functioning field-effect transistors based on single biogenic nanofibers, and study their charge mobility and switching behavior as a function of back-gating, to identify the doping type and majority charge carriers in these semiconductors.