

# **BioWires: Conductive DNA nanowires in a computationally-optimized, synthetic biological platform for nanoelectronic fabrication**

*Simon Vecchioni<sup>a</sup>, Emily Toomey<sup>b</sup>, Mark C Capece<sup>c</sup>, Lynn Rothschild<sup>d</sup>, Shalom Wind<sup>a</sup>*

*<sup>a</sup>Columbia University, <sup>b</sup>Massachusetts Institute of Technology, <sup>c</sup>Stanford University, <sup>d</sup>NASA Ames Center*

DNA is an ideal template for a biological nanowire—it has a linear structure several atoms thick; it possesses addressable nucleobase geometry that can be precisely defined; and it is massively scalable into branched networks. Until now, the drawback of DNA as a conducting nanowire been, simply put, its low conductance. To address this deficiency, we extensively characterize a chemical variant of canonical DNA that exploits the affinity of natural cytosine bases for silver ions.

We successfully construct chains of single silver ions inside double-stranded DNA, confirm the basic dC-Ag<sup>+</sup>-dC bond geometry and kinetics, and show length-tunability dependent on mismatch distribution, ion availability and enzyme activity. An analysis of the absorbance spectra of natural DNA and silver-binding, poly-cytosine DNA demonstrates the heightened thermostability of the ion chain and its resistance to aqueous stresses such as precipitation, dialysis and forced reduction. These chemically critical traits lend themselves to an increase in electrical conductivity of over an order of magnitude for 11-base silver-paired duplexes over natural strands when assayed by STM break junction.

We further construct and implement a genetic pathway in the *E. coli* bacterium for the biosynthesis of highly ionizable DNA sequences. Toward future circuits, we construct a model of transcription network architectures to determine the most efficient and robust connectivity for cell-based fabrication, and we perform sequence optimization with a genetic algorithm to identify oligonucleotides robust to changes in the base-pairing energy landscape. We propose that this system will serve as a synthetic biological fabrication platform for more complex DNA nanotechnology and nanoelectronics with applications to deep space and low resource environments.