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DNA-heattronics: Designing nano-scale thermal devices utilizing the structural transition of DNA

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Abstract

By clamping a piece of DNA in between two metallic leads with slightly different temperatures, a nano-scale thermal junction can be realized using this "molecule of life". DNA has a well-defined structural transition—the denaturation of its double-stranded form into two single strands—that strongly affects its thermal transport properties. We show that, according to a widely implemented model for DNA denaturation, one can engineer DNA 'heattronic' devices that have a rapidly increasing thermal conductance over a narrow temperature range across the denaturation transition (around 80 ^{o}C). The origin of this rapid increase of conductance, or 'switching', is the softening of the lattice and suppression of nonlinear effects as the temperature crosses the transition temperature and DNA denatures. Most importantly, we demonstrate that DNA nano-junctions have a broad range of thermal tunability by varying the sequence and length, and exploiting the underlying nonlinear behavior. We discuss the role of disorder in the base sequence, as well as the relation to genomic DNA. These results set the basis for developing thermal devices out of materials with nonlinear structural dynamics, as well as understanding the underlying mechanisms of DNA denaturation.

Biography

CHIH-CHUN CHIEN obtained his Ph.D in theoretical physics from the University of Chicago in 2009 and he is currently a distinguished J. R. Oppenheimer fellow in the Theoretical Division of Los Alamos National Laboratory. In addition to being an expert on theoretical atomic and molecular physics, he is part of a joint team (with K. A. Kirill, M. Zwolak, and Y. Dubi) working on designing and understanding the fundamentals of nano-scale thermal devices using biomaterials. He has published more than 40 papers in reputed journals.