Applications of DNA in Molecular Electronics

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Overview of Research

While microchips found in everyday electronics have gradually decreased in size until they are now smaller than the point of a sharpened pencil, our group works on research that could one day produce semiconductors that are a million times smaller. A molecule of a material is the smallest particle capable of retaining the physical property of the material. Some molecules possess surprising physical properties that one would not expect. We believe that the DNA molecule is capable of functioning as a semiconductor. Indeed, DNA molecules are perfect nanomachines. Thus the building block of life may become the building block of machines.

Our lab's research into DNA photonics represents collaboration with Argonne National Laboratory, Northwestern University and Boston College, and is sponsored by the National Science Foundation. Our partners have been putting together structures called DNA hairpins, which is a relatively new thing in terms of being able to construct in a laboratory. A DNA hairpin is a single strand of DNA that is bent over like a bobby pin, with several DNA base pairs matched up on each side of the loop. Instead of studying a long strand of naturally occurring DNA that contains thousands of paired bases, scientists prefer to study electron movement in DNA hairpins, where the properties of the DNA are controlled by the deliberate choice of the base pairs contained in it. A small DNA hairpin still offers up everything about its physics, chemistry and biology. Instead of photo-exciting DNA by laser, perhaps one day we will be able to control photo excitation by the sun. Photo excitation by solar energy would permit us to separate a charge and do something with it — that's how a solar cell is supposed to work. The research has implications for bioengineering, medicine and physical chemistry as well as other areas. For instance, DNA molecules may one day be integral in producing electricity more efficiently and less expensively than current silicon solar panels. The way a charge moves through a DNA sequence may one day be instrumental in identifying genetic disorders, genetic damage or viral infections. Many people are looking for the perfect machine, but it literally may be right in the palm of our hands. The art is how to extract the information that we need to know.

Research Objectives:

The main goal of the present project is to address theoretically the question whether DNA can be used as a molecular junction. DNA molecule is charged. It has two electronic charges per each base pair due to phosphate groups in backbones. In biological solution this charge is compensated by Na^+ counterions. If DNA molecule is attached by two its ends to two metals and water is removed from the system the excess charge can be compensated by electrons leaving DNA for those metals. Then DNA molecule becomes similar to n-doped semiconductor and should possess remarkable conductivity. We will examine this opportunity using most-up-to-date computational facilities and a wide variety of experimental data. Our research should provide the background for future DNA applications in nanoelectronics.

Prerequisites or Experience:

The students suppose to obtain almost all necessary knowledge during training. It is desirable that the students have taken two semesters of general chemistry and calculus. A GPA of 3.0 or higher is preferred.