Ideal and Resistive Nanowire Decoders
General models for nanowire addressing

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Recent research in nanoscale computing offers multiple techniques for producing large numbers of parallel nanowires (NWs). These wires can be assembled into crossbars, two orthogonal sets of parallel NWs separated by a layer of molecular devices. In a crossbar, pairs of orthogonal NWs provides control over the molecules at their crosspoints. Hysteretic molecules act as programmable diodes, allowing crossbars to function as both memories and circuits (a PLA for example). Either application requires that NWs be interfaced with existing CMOS technology.

The technology for controlling a large number of NWs with a much smaller number of lithographically produced mesoscale wires (MWs) is called a decoder. A number of methods for producing decoders have been proposed and studied separately. These decoders can all be modeled as embedding resistive switches in NWs, where each switch is controlled by a MW. In this unifying approach, the sequence of switches embedded in a particular NW is termed its "codeword".

All proposed techniques for decoder production involve a significant degree of uncertainty. Nanoscale features cannot be placed precisely. As a result, codewords are assigned randomly to NWs. We believe that stochastic assembly will remain a defining characteristic of nanoscale computing technology. NW decoders provide a highly practical starting point for the more general study of stochastically assembled devices.

We begin this talk by briefly reviewing existing NW and decoder technologies, then present our general model for NW decoders. We define a "simple NW decoder", which uses a pair of ohmic contacts and a set of MWs to control a set a parallel NWs. We also define a "composite NW decoder", which combines multiple simple NW decoders to control a large number of NWs efficiently. We pay particular attention to how these decoders are used in the context of a crossbar.

To understand what qualifies as a properly functioning decoder, we must first describe how MWs control NWs. We provide two models of MW control. In the ideal model, each MW completely turns off some subset of NWs. In the more general resistive model, each MW merely increases each NW's resistance by some positive amount. The ideal model uses binary codewords, while the resistive model uses real-valued codewords.

Binary codewords are a convenient way of describing decoders. Using binary codewords, one can concisely state the conditions a decoder must satisfy. Real-valued codewords, by contrast, are cumbersome to work with. We describe how real-valued codewords can be mapped to binary codewords by adding the notion of "errors" to our ideal model.

In our discussion of errors, we explain how decoders can be made robust. We define the notion of "balanced hamming distance", which accurately captures the criteria a decoder must meet to tolerate permanent defects and certain transient errors. Using this concept, we can bound the number of MWs required to make different types of fault-tolerant decoders. This in turn bounds the size of these decoders.

To conclude, we address the problem of codeword discovery. Since decoders are assembled stochastically, testing is required to discover which codewords are present. This information must be stored to produce a properly functioning decoder. We describe an efficient codeword discovery algorithm which does not require nanoscale measurements or specialized testing circuitry. In contrast, our previous discovery algorithms required the use of hysteretic molecules on which read/write operations could be performed.