Advances Toward Molecular-Scale Electronic Digital Logic Circuits: a Review and Prospectus

James C. Ellenbogen, Ph.D.
Principal Scientist
Nanosystems Group
The MITRE Corporation
McLean, VA 22102
E-mail: ELLENBGN@mitre.org

To continue the ongoing electronics revolution well into the twenty-first century, it is essential that devices and circuits be miniaturized down to the nanometer scale. Two broad approaches exist for achieving such "nanoelectronics." One approach, solid-state nanoelectronics, is attempting to sculpt smaller and smaller features on solid-state semiconductor surfaces in order to manufacture denser computer chips. However, this approach is becoming ever more difficult and costly as miniaturization progresses. A promising alternative approach which may be less costly is to use natural nanometer-scale structures--i.e., individual molecules--to make the electronic components [1].

Molecules can be made precisely, identically, and cheaply in enormous numbers. Moreover, during the past several years there has been great progress in the development and the demonstration of such "molecular electronic" devices, individual molecules that conduct and switch electrical currents.

The speaker will review and explain these recent experimental results that are establishing a foundation for building tiny powerful computational and control systems integrated on the molecular scale. Further, he will describe research at The MITRE Corporation that is building upon these experimental results to propose detailed designs for molecular electronic digital logic circuits and functions. All of these detailed logic designs include only experimentally demonstrated molecular electronic devices as their components [2].

One of these molecular electronic circuit designs describes a molecule that adds two numbers when a current is passed through it. The structure of this molecular electronic half adder is depicted in Figure 1. In the figure, A and B represent the one-bit binary inputs to the adder, while S and C represent the one-bit outputs, the sum and the carry bits, respectively. The corresponding conductive molecules, if realized, would use much less power and they also would be as much as one million times smaller in area than the comparable circuits on a state-of-the-art commercial microcomputer chip [2].

References

[1] D. Goldhaber-Gordon, M. S. Montemerlo, J. C. Love, G. J. Opiteck, and J. C. Ellenbogen, "Overview of Nanoelectronic Devices," *Proceedings of the IEEE*, vol. 85, no. 4, April 1997, pp. 521-540.

[2] J. C. Ellenbogen and J. C. Love, "Architectures for molecular electronic computers: 1. Logic structures using molecular electronic diodes," Report MP 98W0000183, The MITRE Corporation, McLean, VA, March 1999. This report soon will be available on the Internet at the URL: http://www.mitre.org/technology/nanotech

0-7695-0104-4/99 $10.00 © 1999 IEEE

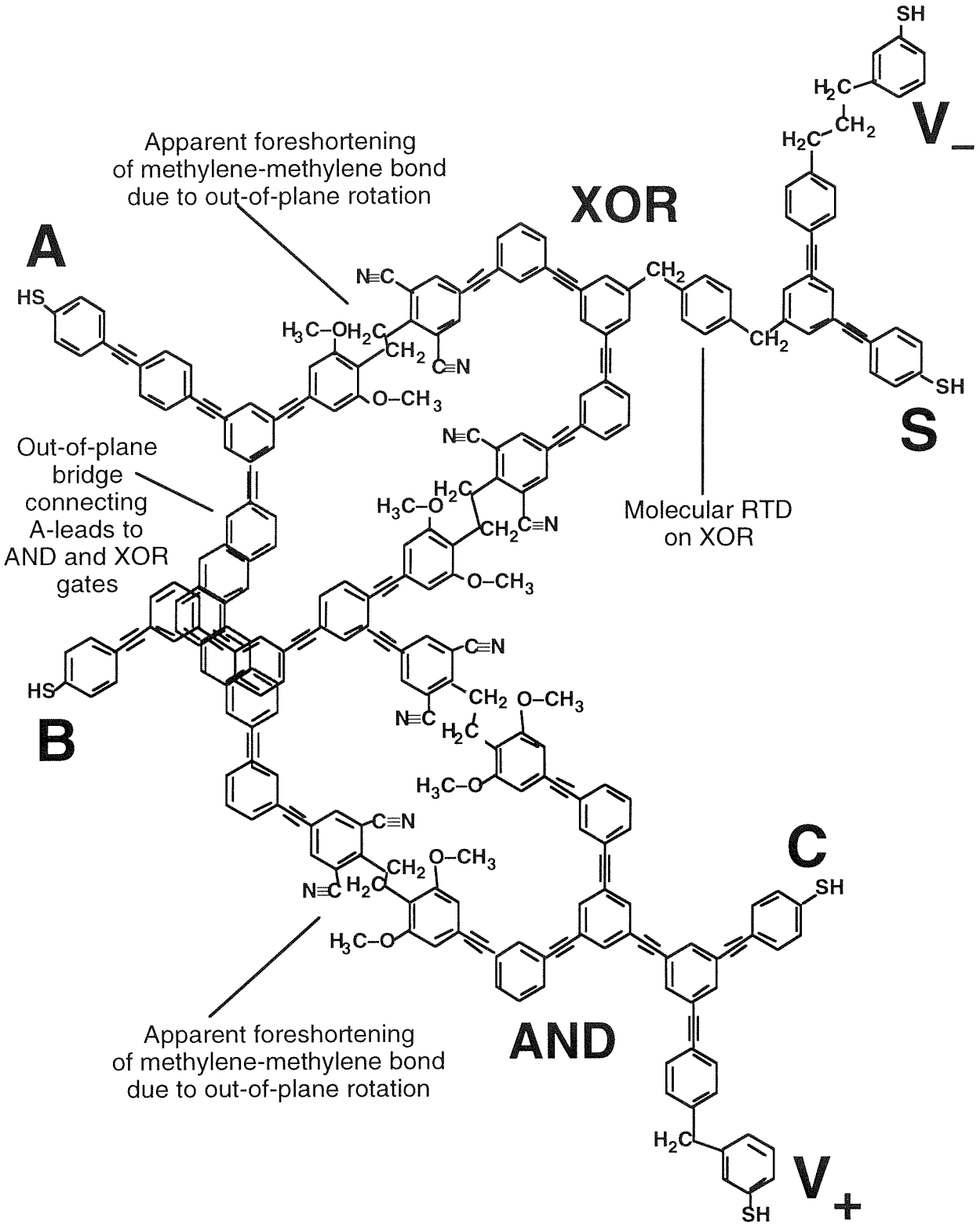

Figure 1. Design for a molecular electronic half adder proposed by The MITRE Corporation. The structure would measure only approximately 10 nm X 10 nm.