Research Open

Nanotechnology and Advanced Material Science

Volume 2 Issue 3

Short Commentary

Where is Unimolecular Electronics?

Robert Melville Metzger*

Department of Chemistry and Biochemistry, University of Alabama, USA

***Corresponding Author:** Robert Melville Metzger, Laboratory for Molecular Electronics, Department of Chemistry and Biochemistry, University of Alabama, Tuscaloosa, AL 35487-0336, USA; **Email:** rmetzger@ua.edu

Received: September 22, 2019; **Accepted:** October 01, 2019; **Published:** October 16, 2019

The field of proposed "unimolecular devices" consisting of a single molecule between measuring electrodes was born in the 1974 theoretical paper by Arieh (now Ari) Aviram and his doctoral adviser Mark A. Ratner [1], which proposed a one-molecule rectifier (=one-way conductor) of electricity, as the molecular equivalent of the inorganic "pn junction" rectifier using macroscopic "p or n-doped" semiconductors.

The first such rectifier was a heterojunction monolayer in 1990 [2], confirmed in 1993 [3] and proven as a homojunction monolayer rectifier in 1997 [4]. Since then, at least 50 rectifiers have been studied world-wide, along with many more unimolecular wires [5–7].

The hope had been that such unimolecular devices (of size 2 nm each)could match or replace the competing gradual yet dramatic decrease in component size of inorganic semiconductor devices in integrated circuits (Moore's "law") [8]. That hope has been dashed [7] because (i) the currents measured through single molecular wires or rectifiers have varied by two to three orders of magnitude (high dispersion), (ii) the proposed molecular equivalent of a junction transistor [9] has not been realized, (iii) the rectification ratios have remained too small (but see below), and (iv) because of limited funding.

There has been, however some hopeful progress:

a) Nijhuis and co-workers have seen rectification in monolayers of alkyne-linked bisferrocene with a pentadecanethiol "tail" sandwiched between template-stripped Pt and Ga In eutectic electrodes that reached a rectification ratio RR(V) = –I(V)/I(–V) of 630,000 [10];

b) Cyganik and co-workers have created a periodic closed-packed monolayer of a phenylcarbene covalently bonded to Au (111) but have not yet measured any currents across the monolayer [11]: in the future this may facilitate a current through these carbenes with minimal dispersion, as the best way to measure unimolecular wires and rectifiers (if the other end can also be suitably bonded to the second electrode in similar close-packed fashion). Never, never, never, never give up [12].

References

1. Aviram A, Ratner MA (1974) Molecular Rectifiers. *Chem Phys Lett* 29: 277–283
2. Ashwell GJ, Sambles JR, Martin AS, Parker WG, Szablewski M (1989) Rectifying Characteristics of Mg |(C16H33-Q3CNQ LB Film) | Pt Structures, *J Chem Soc Chem Commun* 1989: 1744–1376.
3. Martin AS, Sambles JR, Ashwell GJ (1993) Molecular Rectifier. *Phy Rev Lett* 70: 218–221.
4. Metzger RM, Chen B, Hoepfner U, Lakshmi kantham MV, Vuillaume D, et al. (1997) Unimolecular Electrical Rectification in Hexadecyl quinolinium Tricyano quinodi methanide. *J Am Chem Soc* 119: 10455–10466.
5. Metzger RM (2003) Unimolecular Electrical Rectifiers. *Chem Rev*. 103: 383–3834.
6. Metzger RM (2015) Unimolecular Electronics. *Chem Rev* 115: 5056–5115.
7. Metzger RM (2018) Quo Vadis, Unimolecular Electronics? *Nanoscale* 10: 1016–10332
8. Moore GE (1965) *Electronics* 38: 114.
9. Toher C, Nozaki D, Cuniberti G, Metzger RM (2013) Unimolecular Amplifier: Principles of a Three-Terminal Device with Power Gain. *Nanoscale* 5: 6975–6984.
10. Chen X, Roehmer M, Yuan L, Du W, Thompson D, et al. (2017) Molecular Diodes with Rectification Ratios Exceeding 10^3 Driven by Electrostatic Interactions. *Nature Nanotechnol* 12: 797–803.
11. Cyganik P (Jagiellonian University, Krakow), unpublished results.
12. Sir Winston Churchill, high-school graduation speech, ca. 1941.

Citation:
Robert Melville Metzger (2019) Where is Unimolecular Electronics? *Nanotechnol Adv Mater Sci* Volume 2(3): 1–1.