Making the Tiniest Machines

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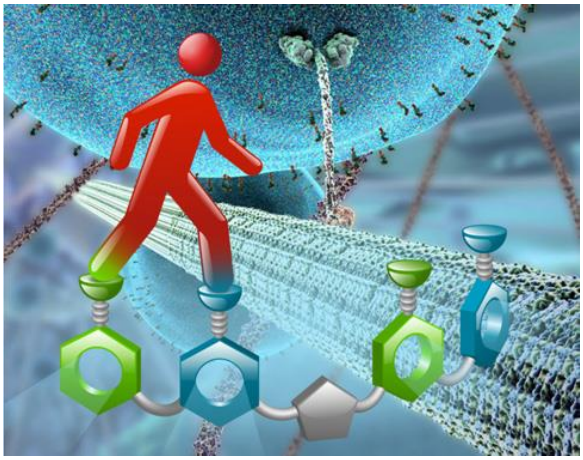
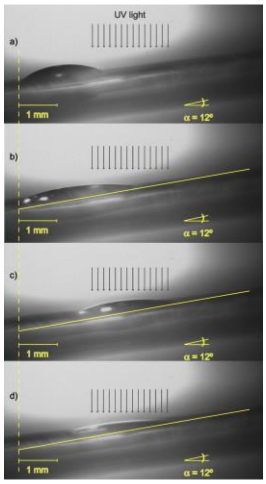
"*We are at the dawn of a new industrial revolution of the twenty-first century, and the future will show how molecular machinery can become an integral part of our lives. The advances made have also led to the first steps towards creating truly programmable machines, and it can be envisaged that* molecular robotics *will be one of the next major scientific areas.*"[1]

The 2016 Nobel Prize in Chemistry Committee, October 2016

Over the past few years some of the first examples of synthetic molecular level machines and motors—all be they primitive by biological standards—have been developed.[2-7] These molecules respond to light, chemical and electrical stimuli, inducing motion of interlocked components held together by hydrogen bonding or other weak molecular interactions. Recently the first programmable systems have been developed,[4,5] the forerunners of a new technological era of molecular robotics.

Perhaps the best way to appreciate the technological potential of controlled molecular-level motion is to recognise that nanomotors and molecular-level machines lie at the heart of every significant biological process. Over billions of years of evolution Nature has not repeatedly chosen this solution for achieving complex task performance without good reason. In stark contrast to biology, none of mankind's fantastic myriad of present day technologies exploit controlled molecular-level motion in any way at all: every catalyst, every material, every plastic, every pharmaceutical, every chemical reagent, all function exclusively through their static or equilibrium dynamic properties. When we learn how to build artificial structures that can control and exploit molecular level motion, and interface their effects directly with other molecular-level substructures and the outside world, it will potentially impact on every aspect of functional molecule and materials design. An improved understanding of physics and biology will surely follow.





[1] *The Nobel Prize in Chemistry 2016–Advanced Information*. Nobelprize.org. Nobel Media AB 2014. Web. 6 Oct, 2016, http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2016/advanced.html. [2] E. R. Kay and D. A. Leigh, *Angew. Chem. Int. Ed.*, 2015, **54**, 10080. [3] B. Lewandowski, et al., *Science*, 2013, **339**, 189. [4] S. Kassem, A. T. L. Lee, D. A. Leigh, A. Markevicius and J. Solá, *Nat. Chem.*, 2016, **8**, 138. [5] S. Kassem, A. T. L. Lee, D. A. Leigh, V. Marcos, L. I. Palmer and S. Pisano, *Nature*, 2017, **549**, 374. [6] S. Erbas-Cakmak, S. D. P. Fielden, U. Karaca, D. A. Leigh, C. T. McTernan, D. J. Tetlow and M. R. Wilson, *Science*, 2017, **358**, 340. [7] M. R. Wilson, J. Solá, A. Carlone, S. M. Goldup, N. Lebrasseur and D. A. Leigh, *Nature*, 2016, **534**, 235.