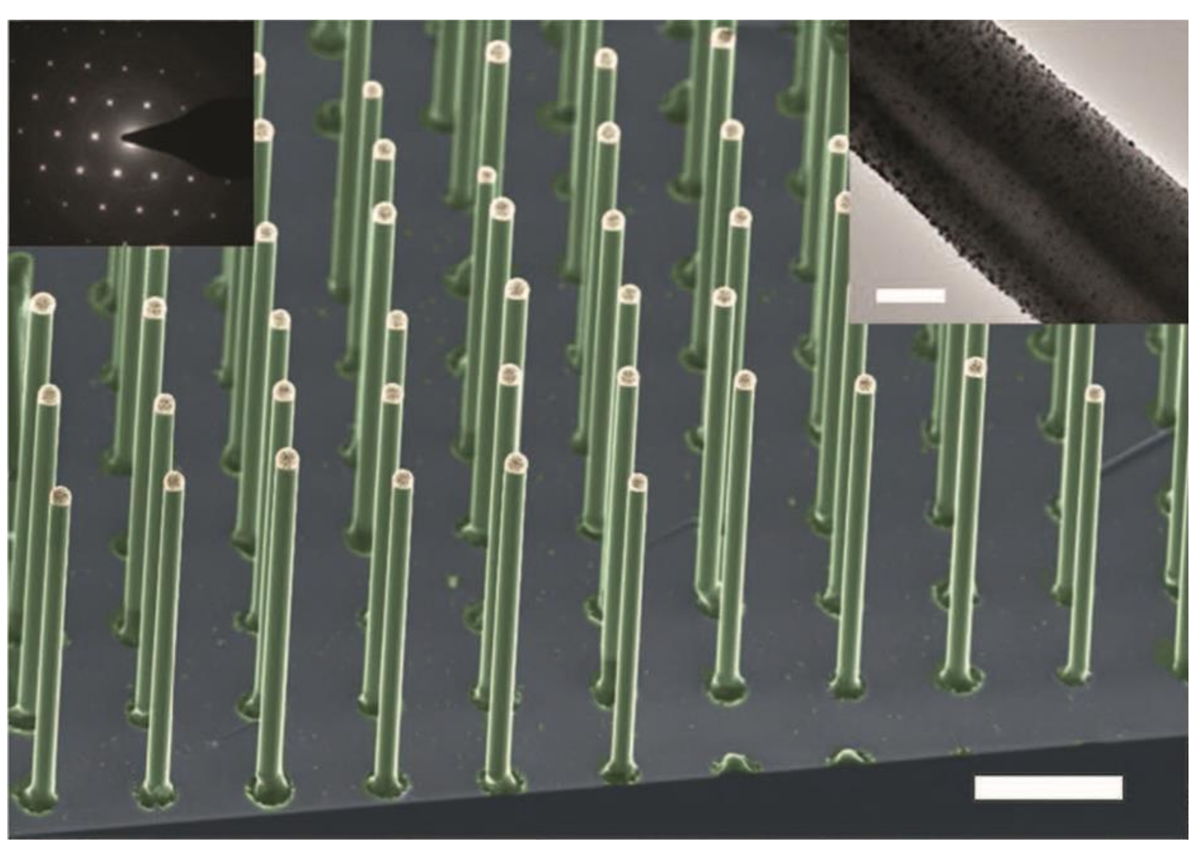
A Silicon Nanowire as a Spectrally Tunable Light-Driven Nanomotor

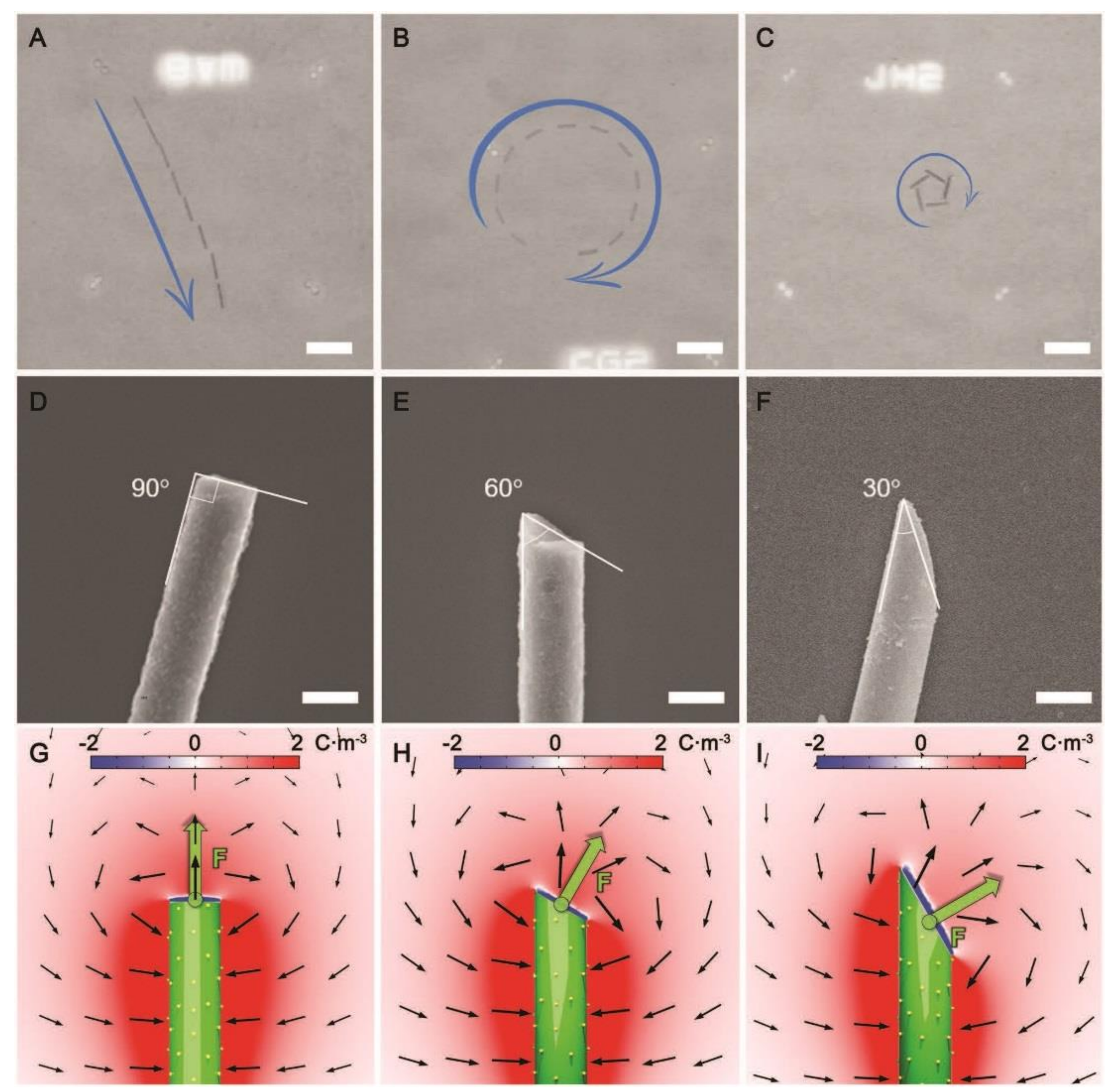
Jizhuang Wang, Ze Xiong, Jinyao Tang
Department of Chemistry, University of Hong Kong

Introduction: Over the last decades, scientists have endeavored to develop nanoscopic machines and envisioned that these tiny machines could be exploited in biomedical applications and novel material fabrication. Here, a visible-near-infrared light-driven nanomotor based on a single silicon nanowire is reported. The experimental study and numerical simulation also show that the detailed structure around the concentrated reaction center determines the migration behavior of the nanomotor.



Computational Methods: COMSOL Multiphysics (version 5.2) was used to solve the H+ and OH− concentration, the charge distribution, and the electric field. 3D simulations were used for rod-shaped Si nanomotors. Outside Si nanomotor, a cylinder of fluid was placed (50 μm in length and 25 μm in diameter). The anode (H+) and cathode (OH−) fluxes on the nanowire surface were set according to the measured photocurrent. The H+ and OH− flux were kept to be equal in value on both ends at all times to conserve charge neutrality. A predefined finer mesh for fluid hydrodynamics was used for the fluid domain. A fine mesh condition was chosen at the end of Si nanomotor to clarify the charge distribution. A free tetrahedral mesh was used to generate 117 431 elements. A stationary simulation was carried out to calculate the system at steady state.

Results: Different motion trajectories induced by different nanowire end surface morphology. A–C) Superimposed images of sequential frames of nanowires with different motion trajectories: “linear,” “circular,” and “rotational.” The scale bar is 20 μm. D–F) SEM images of different nanowire p–n junction ends correspond to three different migration trajectories. The scale bar is 500 nm. G–I) Numerical simulation of charge distribution (color map), the electric field (black arrows, the arrow length logarithmically represents the electric field intensity) of different nanowire ends. The green arrow denotes the repelling force direction exerted on end surface by surrounding solutions.



Conclusion: We have successfully demonstrated a lightpowered silicon nanowire-based nanomotor that can be propelled by ultralow-intensity visible or near-infrared illumination. By utilizing the optical resonance in the nanowire, the spectral response of nanowire motor can be controlled, which offers a new protocol for nanomotor design.

Reference:

[1] J. Wang, W. Gao, *ACS Nano* **2012**, *6*, 5745.
[2] D. Patra, S. Sengupta, W. Duan, H. Zhang, R. Pavlick, A. Sen, *Nanoscale* **2013**, *5*, 1273.
[3] J. G. S. Moo, M. Pumera, *Chem. Eur. J.* **2015**, *21*, 58.