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Preview

Nanowires Pin Neurons: a Nano ''Moon Landing''

Xingcai Zhang[1,*]

Recently, Harvard University scientists initiated a nano ''moon landing.'' They developed hairpin-like nanowires to land and pin neurons to study their inner signals without cellular damage, decoding the communication within and between neuron networks and providing tools for future brain disease studies.

From nanowires to neurons, our understanding of the physical and biological world advances with the efforts of bold innovators. Charles Lieber, a University Professor at Harvard University, is one of the most eminent nanoscientists in the world. His pioneering work on nanowires and nanodevices has led us to a flourishing world of nanoscience and nanotechnology, bridging the fields of chemistry, materials, electronics, and biology. His progress in neuron studies is similar to the ambitions of the moon landing: the exploring of a new and fantastic (nano-)world.

Since the emergence of nanotechnologies, our understanding of the physical world has advanced rapidly. We can poke and probe many materials at the nanoscale and measure properties and behaviors. However, the understanding of the biological world, especially the brain, is still in its infant stage. It is difficult to poke and probe such ''living'' materials—they tend to change rapidly and produce very complex signals, like radio channels with static and distortion. The development of hairpin-like nanowires to cross the neuron membranes and pin neurons to study their inner signals is an important advancement, as described by Zhao et al. from the Lieber group recently in *Nature Nanotechnology*.[1] We can now directly read from neurons. Let us shuttle through the nano-pin to explore this new ''moon'' of possibilities.

This recent study improves our ability to physically tap into messages between neurons and their interactions. Neurons are nerve cells in the brain. The human brain contains about 86 billion neurons that are wired into complex circuits to process information conveyed by electrical signals. Neurons are electrically excitable and use electrical currents to function and signal to one another. As such, reading electrical activities from neurons is the basis of understanding of the brain. Decoding the communication between neurons helps us to understand brain functions. Translating the brain activities into control signals for devices, such as artificial limbs, assists people with paralysis. Most of the tools developed today read brain activities by picking up signals that are leaked outside of the neurons[2]—like listening to voices behind a closed door. To achieve the most accurate functional readings and the finest control of neural activities, direct access to the interior of neurons is critical[3]—we want to be in the same room! The most conventional method for intracellular recording is the patch-clamp

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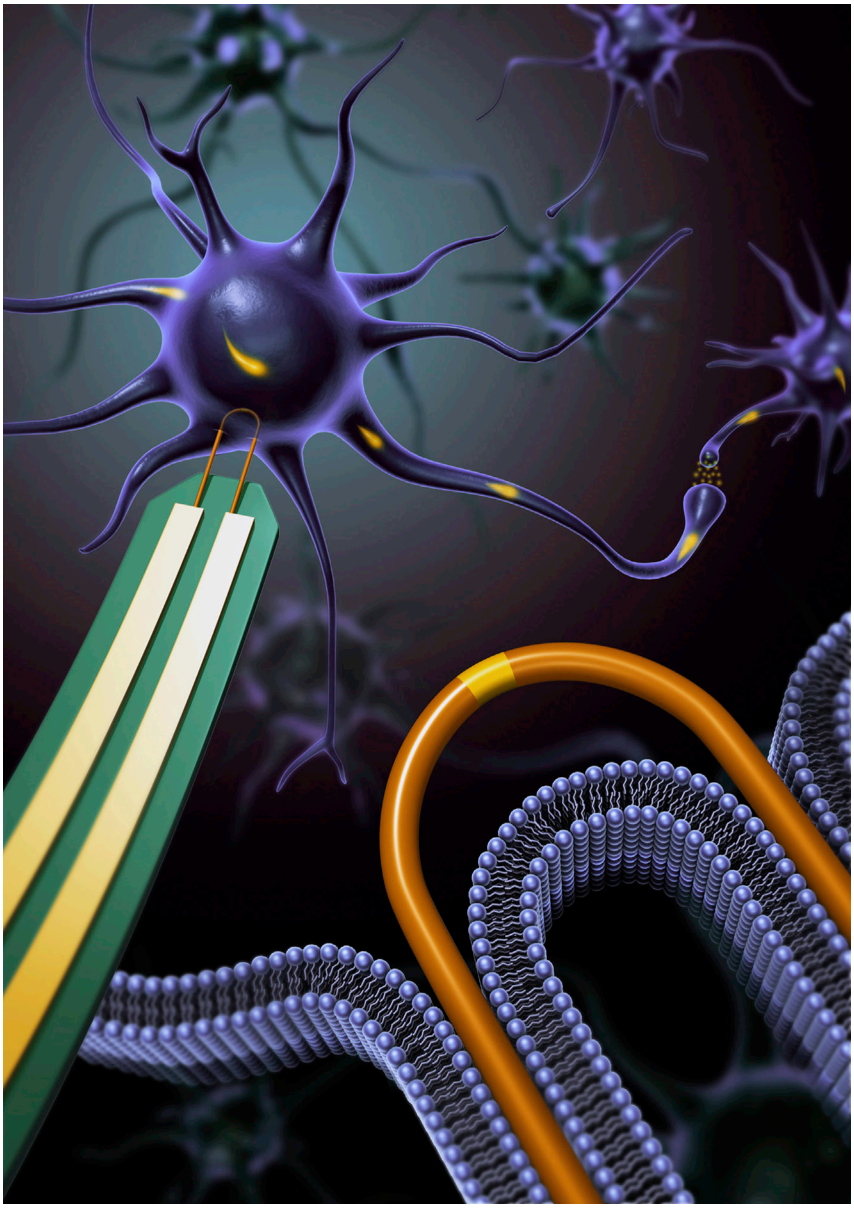

Figure 1. Nanowires Pin Neurons: a Nano "Moon Landing" (Figure Credit: Lieber Group, Harvard University)

electrode.[4] It causes irreversible damage to neurons by its micrometer-scale tip—akin to getting in the room by breaking the door (or even the walls). Even then, it can only record a few cells at a time. To circumvent such issues, Lieber and co-workers developed a hairpin-like 3D nanowire transistor array to cross the neuron membranes and pin neurons for interior signal study.[1] Their study showed no identifiable cellular damage—e.g., entering the room with a smart nanokey without any damage. Moreover, they were able to study multiple neurons' interior electrical activities at the same time.

As shown in Figure 1 (figure credit: Lieber Group, Harvard University), the work is based on the group's niche in nanowire fabrication technology.[5] They first made straight p-type silicon nanowires (precisely 15 nm in diameter; very high length-to-width ratio). The nanowires are as flexible as cooked noodles. To achieve the right conformation, they "combed" the nanowires over the U-shaped trenches of a predesigned pattern on a silicon wafer. When tangles are removed from the nanowire hair, the shearing force deforms the nanowires to form an array of hairpin-like U-shaped nanoscale devices. They then produced a controlled length of field-effect transistor (FET) sensing elements, which can be used as tiny recorders, at the tips of each nanowire. The tips can be inserted into neuronal and cardiac cells for intracellular recording with signals comparable to those of the gold-standard patch-clamp electrodes. As the nanowire tips are so small and coated with a layer of molecules that mimic the cell membrane, they can be inserted into multiple cells in parallel without causing damage. In addition, they found a strong correlation between probes with smaller curvature and recorder sizes and easier internalization and thus better intracellular recording quality, which is consistent with the nanoscale curvature effect.[6] They further fabricated multiple nanowire devices on a single probe arm to read from multiple locations in a single cell. They also fabricate tens of the probes to record signals from adjacent cells simultaneously to study signal propagation between cells. These modifications have the potential to make better tools for decoding the communication within and between complex neuron networks.

The work of Zhao et al.[1] achieves a major step ahead in probing neurons and paves the way for improving our understanding of the brain and brain-related diseases. They integrate nanoscale building blocks into large controllable arrays. They address the long-standing challenge of scalable intracellular electrical recording with minimal invasiveness. Besides, their nanowire-based fabrication technology can be incorporated into other platforms like free-standing probes and mesh electronics. They could enable precise targeting of individual cells or subcellular structures. They can also be applied for further *in vivo* studies,[7] single-neuron chronic recording,[8] and bioinspired neuron-like electronics,[9] etc. In the longer term, these probes could ultimately drive advanced brain-machine interfaces and possibly contribute to treating neurological and neurodegenerative diseases.

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Preview

How to Make a Most Stable Perovskite Solar Cell

Mohammad Z. Rahman[1,*] and Tomas Edvinsson[1,*]

Perovskites have emerged as one of the hottest solar cell materials in the recent years, evident by more than 6,000 publications in 2018. Although intense research efforts on perovskite materials have made a significant progress in understanding its fundamental physicochemical properties, a long-term stability of perovskite solar cells (PSC) under operating conditions remains elusive. This article previews the recent findings on most stable PSC to date. Notably, an integrated effort of collaborative research has presented a simple but broadly applicable method to enhance the long-term operational stability of perovskite solar cells (over 1800 h at 70-75°C) under continuous simulated full-spectrum sunlight, which is up to ten times more stable than previous most stable devices.

Intrigued by its beneficial optoelectronic properties—such as tunable band gap, strong light absorption, charge carrier mobility, defect tolerance, and simple synthesis procedures—in the recent years, metal halide perovskites have drawn great interest for making highest efficient thin-film solar cells.[1–3] Despite being a new member in solar cell family, perovskite solar cells (PSC) have shown steady and remarkable progress in increasing the power conversion efficiency (PCE) of ~24.2% for standalone PSC and ~28% for perovskite-silicon tandem structure.[4] However, the stability of PSCs at rated PCE for long-operational hour remains a grand challenge. There is no exception, but a solar cell material must be intrinsically stable to the light exposure and ambient so that the solar cell remains operational for >25 years.[5] Therefore, while the power conversion efficiency is an important figure of merit for a solar cell, actually, stability is the main determining selection criteria.[6]

What is the origin of the instability in PSCs? Simply, the origin is a result of cumulative impacts caused by multiple factors associated with the structure and components of a given perovskite when expose to the light, humidity, and temperature. Structurally, perovskites can be represented by the formula ABX_3, where A is usually a mixture of methylammonium (MA), formamidinium (FA), and cesium (Cs); B is a mixture of tin (Sn) and lead (Pb); and X is a mixture of iodine (I) and bromine (Br); but there can be other components, as well (such as Cl, F, etc.).[7] The moisture induces reversible and irreversible degradation of perovskite films. Perovskites easily take on water and the penetrated water molecules form an intermediate monohydrate and dihydrate perovskite. Light induces photo-oxidation and segregation of halide and cation, while temperature results in sublimation of the organic and halide components

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