Modeling Random Memristive Nanowire Networks

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Introduction

Standard computer CMOS technology is nearly at size and speed limits, prompting investigation into alternative computer architectures to continue the 50-year exponential rise in computing power.

Nanowires (NW), 10nm x 1μm metal or semiconductor structures, can form high-performance electronic components at crossed NW-NW junctions.

Here, we investigate electrical properties of random networks of PVP@Ag nanowires via computer model in search of computational applications.

Experiments

Previous research has constructed random networks of insulator-on-metal nanowires, hypothesized a sort of memristor at a NW-NW junction, and created patterns of low-resistance pathways between given electrodes in a network.

The internal dynamics of such networks are not clear. Here, we create a computer model of the network to investigate such internal dynamics. We find just two simple competing behaviors.

Second, we confirm model realism by physical experiment. We find memristor decay time is on the order of weeks.

Conclusions

The simulation and junction model seem valid. Because the network is so simple, the network exhibits no complex persistent dynamics.

APPLICATIONS:
- custom finite state machine electronics:
  clever electrode arrangements make current switches without CMOS tools
- ephemeral memory:
  store bits for a constant finite time (for this network, weeks)
- planar memristance

FUTURE WORK:
- increased control of network parameters
- add capacitance for more dynamics

References & Thanks

Gimzewski et al., Nanotechnology (2013)
Chu et al., Acta Materialia (2008)

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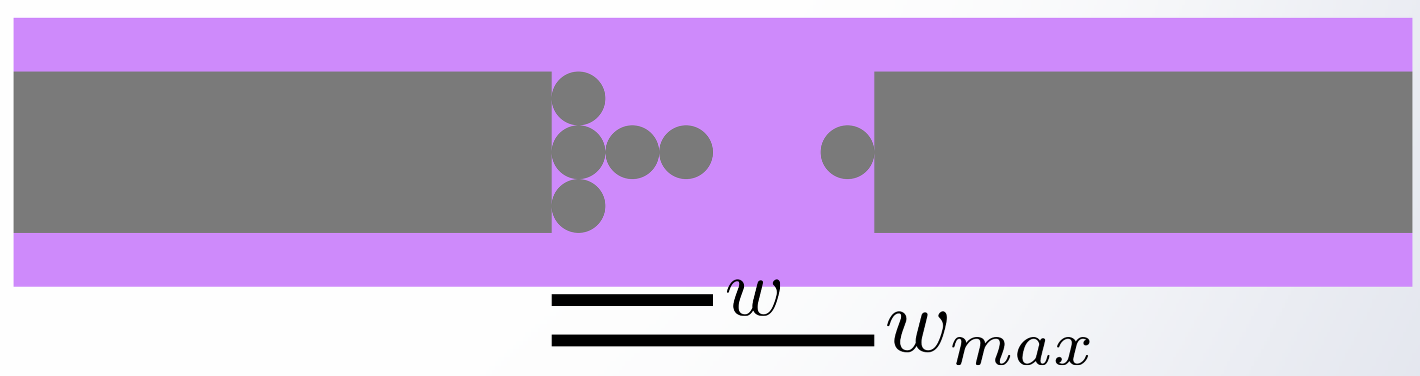
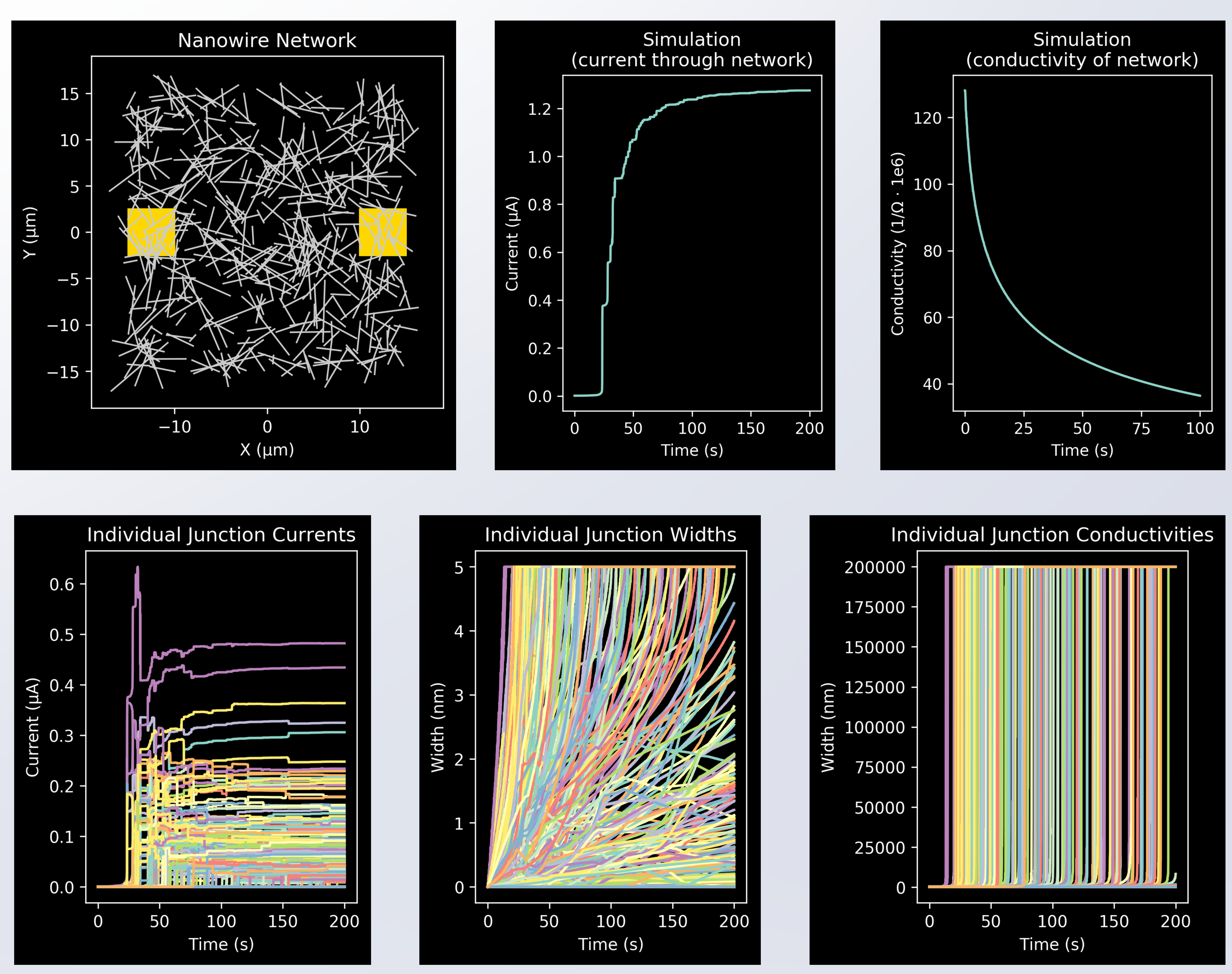
NANOWIRE MODEL

$$V = \left[\frac{w}{w_{max}} \cdot R_{on} + \left(1 - \frac{w}{w_{max}}\right) \cdot R_{off}\right] \cdot I \qquad \frac{dw}{dt} = \mu_v \cdot \frac{R_{on}}{w_{max}} \cdot |I| - \frac{w}{\tau}$$



Consider Ag NWs with ~5nm polyvinylpyrrolidone (PVP) coating and negligible resistance. A NW-NW junction acts as a resistor with resistance (top left) a linear combination of on and off resistance. Juntion filament width changes (top right) with current and decreases with time.

COMPUTER SIMULATION



Clockwise from top left:

(a) A computer model of multiple nanowires randomly assembled on two electrodes.

(b) Current response of network to a constant voltage.

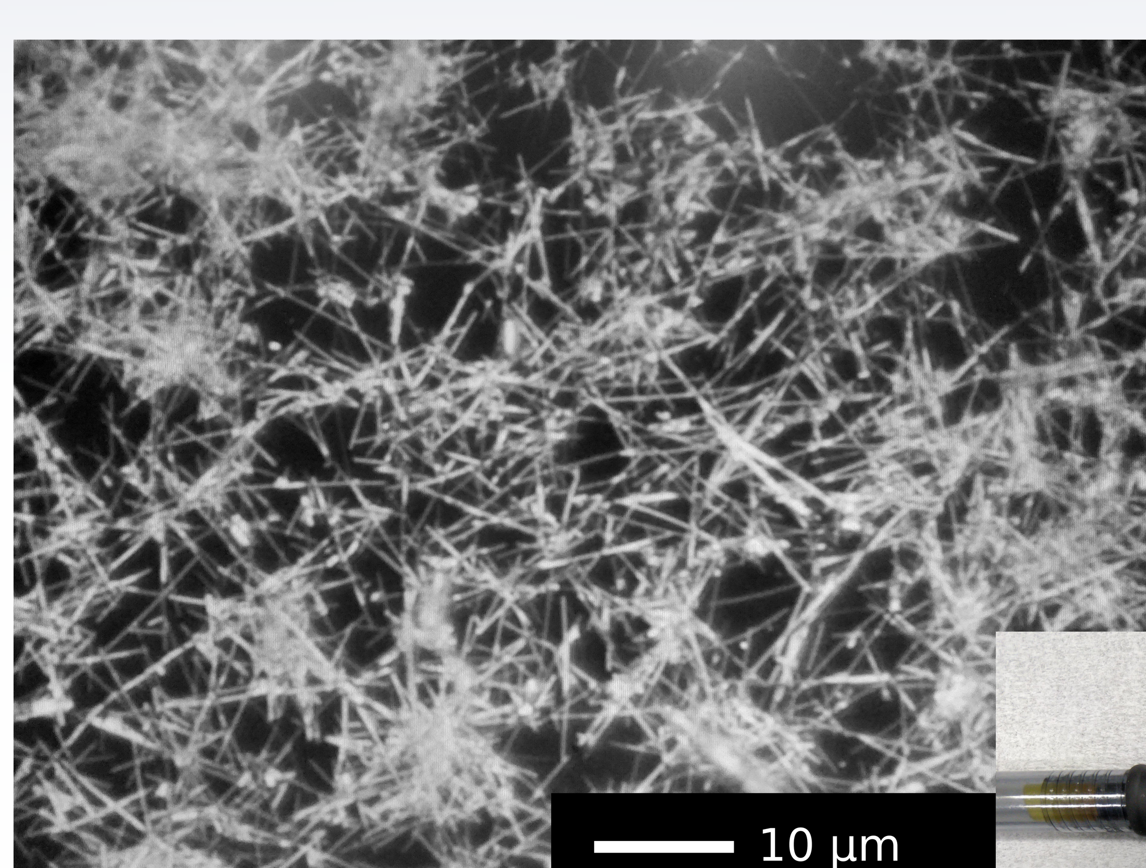
(c) Total conductivity of network decreases when current is removed.

(d) As constant voltage is applied, junctions switch quickly from high to low resistance.

(e) At the same time, junction widths are governed by a rising curve - due to current - or falling exponential - time decay.

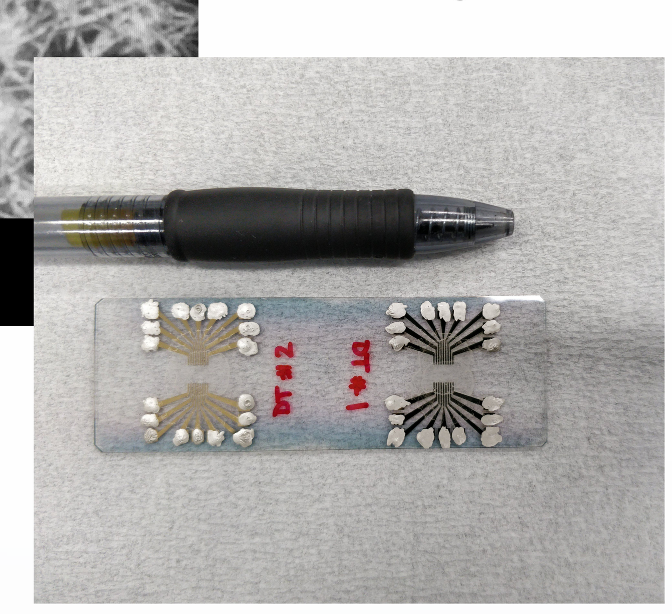
(f) Current switches chaotically through junctions before reaching a steady state.

PHYSICAL VALIDATION

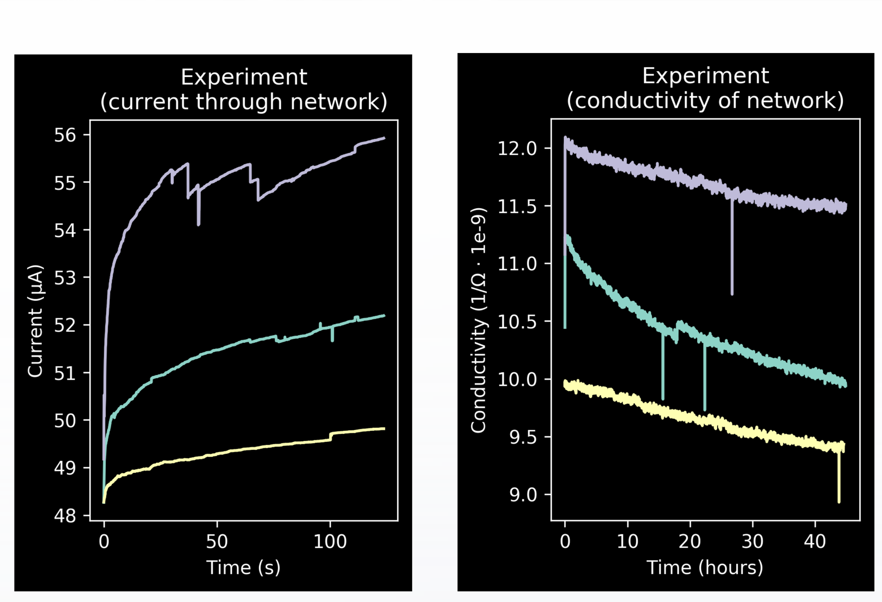


Top left: the physical nanowire network. Nanowires are about 50nm wide and 10μm long, scattered at a density on the order of 1 NW / square μm on glass and gold electrodes

Middle right: Two networks on gold electrodes.



Bottom left and right: current through two electrodes on three physical networks under constant voltage, and conductivity of same under negligible current. Compare with (b) and (c) above.



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