Synthetic synapses get more like a real brain

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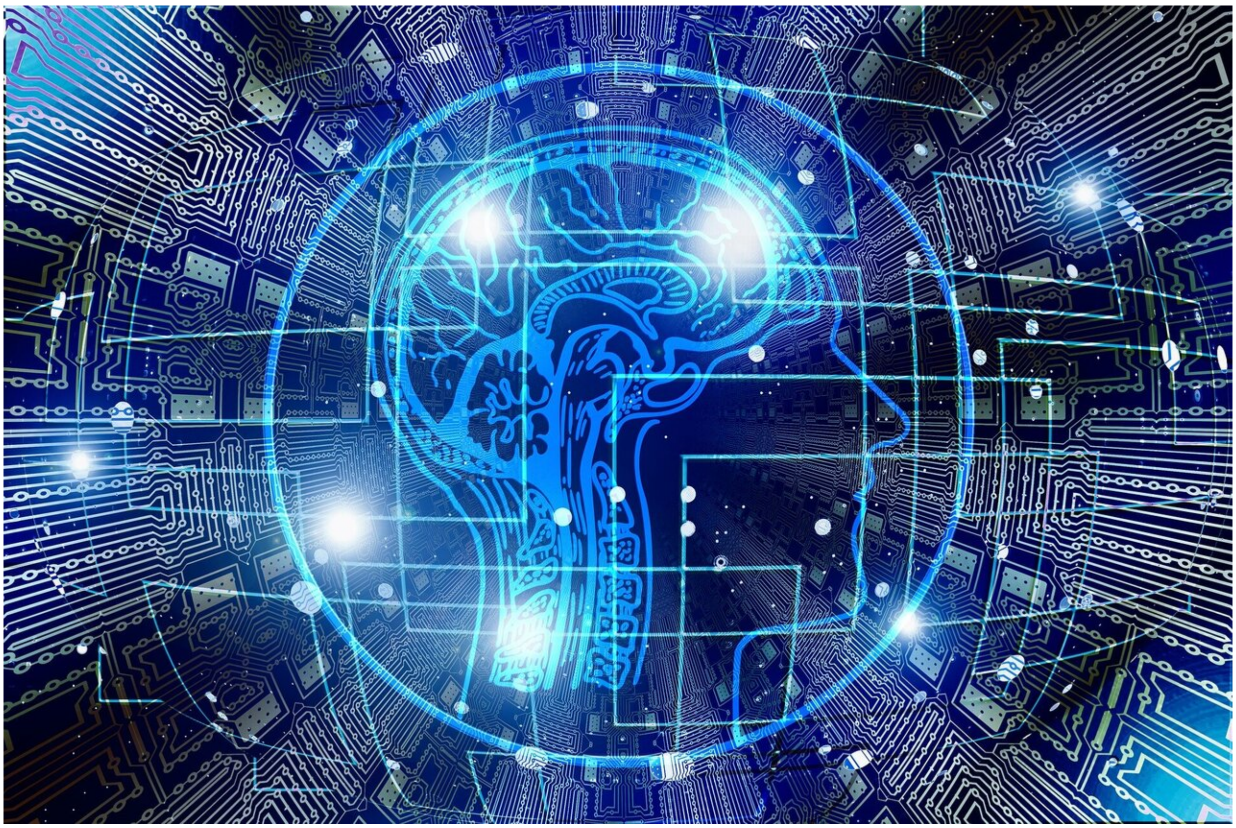

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The human brain, fed on just the calorie input of a modest diet, easily outperforms state-of-the-art supercomputers powered by full-scale station energy inputs. The difference stems from the multiple states of brain processes versus the two binary states of digital processors, as well as the ability to store information without power consumption—non-volatile memory. These inefficiencies in today's conventional computers have prompted great interest in developing synthetic synapses for use in computers that can mimic the way the brain works. Now, researchers at King's College London, UK, report in *ACS Nano Letters* an array of nanorod devices that mimic the brain more closely than ever before. The devices may find applications in artificial neural networks.

Efforts to emulate biological synapses have revolved around types of memristors with different resistance states that act like memory. However, unlike the brain the devices reported so far have all needed a reverse polarity electrical voltage to reset them to the initial state. "In the brain a change in the chemical environment changes the output," explains Anatoly Zayats, a professor at King's College London who led the team behind the recent results. The King's College London researchers have now been able to demonstrate this brain-like behavior in their synaptic synapses as well.

Zayats and team build an array of gold nanorods topped with a polymer junction (poly-L-histidine, PLH) to a metal contact. Either light or an electrical voltage can excite plasmons—collective oscillations of electrons. The plasmons release hot electrons into the PLH, gradually changing the chemistry of the polymer, and hence changing it to have different levels of conductivity or light emissivity. How the polymer changes depends on whether oxygen or hydrogen surrounds it. A chemically inert nitrogen chemical environment will preserve the state without any energy input required so that it acts as non-volatile memory.

The junction can be set and read either optically or electrically or set one way and read the other allowing great versatility. "One advantage of optical control is you can wirelessly switch and read the device," says Zayats. The preference for electrical or optical operations depends on the application, but as he points out, there have been a number of attempts to create neuromorphic circuits that compute the way the brain does, and if you introduce optical switching or read out you can compute faster.

The researchers stumbled on the polymer junction's neatly synaptic behavior during experiments to develop a nanoscale light source. They had constructed different tunnel PLH junctions, and noticed the light source was not stable in air or hydrogen. "By chance I read a paper about synapses and thought—that is our light source," says Zayats. "It was completely by chance."

The density of the synaptic nanorod arrays Zayats and colleagues report gets impressively close to the synaptic density of the brain, falling short by just a factor of thousand or so. The next challenge will be finding a way to switch individual nanorods instead of the whole array, which would bring them yet another step closer to mimicking the brain.

More information: Pan Wang et al. Optoelectronic Synapses Based on Hot-Electron-Induced Chemical Processes, *Nano Letters* (2020). DOI: 10.1021/acs.nanolett.9b03871

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