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ORGANIC ELECTRONICS

Under pressure

> “We developed a bionic tactile perception system based on two organic transistors for prosthetic products and artificial intelligence applications”

An electronic element based on organic transistors can sense pressure and process the resulting signals in a similar way to neurons. As Daoben Zhu and colleagues report in *Advanced Materials*, this system represents a step forward for the fabrication of flexible electronic skin devices that mimic the functionality and sensitivity of skin.

Flexible sensors that respond to external stimuli through their transduction into electrical signals already exist. However, for the development of perception systems that mimic biological function, the ability to further process electrical signals is required. The new functional element is based on two organic field-effect transistors — a ‘sensing’ transistor and a ‘synaptic’ transistor — that, combined, provide the desired sensing and signal-processing functionalities. “We developed a bionic tactile perception system based on two organic transistors for prosthetic products and artificial intelligence applications,” remarks Zhu. The use of organic semiconductors is motivated by their biocompatibility, low cost and flexibility.

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The sensing transistor, which has a suspended gate that deforms under pressure and modifies the conductivity of the device, is a well-developed component. By contrast, the fabrication of the synaptic transistor, which mimics the synaptic connection between neurons, was a big challenge. “Organic-based bionic tactile perception systems with integrated sensing and neuron-like information processing functionalities have not been realized before, owing to the slow development of signal-processing elements and their integration with sensing devices,” explains Zhu.

Voltage pulses reaching the gate of the transistor act like presynaptic stimuli in neurons, whereas the current in the channel of the transistor is the equivalent of postsynaptic activity. Although the electrical performance of the synaptic transistor is not as good as that of conventional organic transistors, it is sufficient to demonstrate synaptic operation. Important features of neuronal transmission are excitation of a postsynaptic current in response to a negative presynaptic spike (a negative voltage pulse) and excitation of an inhibitory postsynaptic current in the presence of a positive presynaptic spike (a positive voltage pulse). The device successfully reproduces these basic features of neuronal transmission.

Moreover, neurons process information by adapting the strength of the synapse’s response to subsequent stimuli; for example, if a second spike closely follows an initial one, it will excite a stronger current compared with that of the first spike. This behaviour is realized in the synaptic transistor if the two pulses are close enough that the charges perturbed by the first spike do not reach equilibrium before the arrival of the second spike, amplifying its effect. However, if many spikes arrive in close succession, the postsynaptic current in neurons decreases; the synaptic transistor also mimics this behaviour, probably, according to the researchers, owing to carrier trapping phenomena.

In the tactile perception device, the application of pressure changes the conductivity in the sensing transistor, delivering a voltage to the gate of the synaptic transistor. Because the response of the synaptic transistor depends on the applied stimuli, the current collected from the device contains combined information on the intensity, frequency and duration of the applied pressure. By fabricating small perception arrays, the researchers could collect spatially resolved information on the patterns of applied pressure.

“Although we firmly believe that this tactile perception system holds promise for applications in electronic skin and other artificial intelligence applications, we do not think that realistic applications can be envisaged in the near future, because many fundamental challenges still lie ahead,” concludes Zhu. For example, it is difficult to extract quantitative tactile information about the applied pressure with the current sensor. Other issues that need addressing are decreasing power consumption and large-scale integration of the sensor with other components.

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