

# Multifunctional Organic PhotoTransistor: Integrating Volatile and Non-Volatile Memory in a Single Device

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Artificial neural networks rely on the interplay between signal integration and memory, typically implemented through complex circuit architectures with significant computational overhead. [1] The development of device-level elements, capable of simultaneously reproducing these functions, offers a route toward more compact and energy-efficient neuromorphic systems. [2] Organic electronic devices provide a versatile platform for this purpose. However, most approaches still rely on separate components or multi-device configurations to emulate neuron- and synapse-like behavior. [3] Here, we address this limitation by developing an organic phototransistor (OPT) that integrates *both* functionalities within a single device. The device is based on a hybrid dielectric architecture (ITO/PVDF-TrFE-CFE/radical-doped PMMA/C8-BTBT/Ag), combining a relaxor-like ferroelectric polymer with an optically modulated dielectric layer. The radical-doped PMMA incorporates the persistent radical PyPBTM, a material previously employed in bulk heterojunction systems (e.g., with DPP:DTT) which exhibited neuromorphic responses. In this case, it enables enhanced charge modulation and memory effects. [4,5] Moreover, this new device exhibits distinct neuromorphic functionalities depending on the mode of stimulation. Under electrical excitation, it shows spike-number-dependent plasticity (SNDP), corresponding to short-term potentiation (STP) which enables a leaky integrate-and-fire response with reversible relaxation to a stable baseline (maintained over  $\geq 100$  cycles). Under optical excitation (405 nm), it instead displays long-term potentiation (LTP) and paired-pulse facilitation (PPF), which results in a stable, history-dependent modulation of the channel conductance (characteristic of synaptic weight storage). The coexistence of electrically driven STP and optically induced LTP within a *single* device demonstrates the feasibility of implementing both neuron-like and synapse-like functions at the device level. This approach provides a compact platform for simplified neuromorphic hardware, and supports the development of integrated artificial neural networks and neuromorphic vision systems.

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