Title: Neuromorphic functionalities and *in-material* reservoir computing with light-responsive materials

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Understanding and emulating fundamental functions of biological systems has become a key challenge in modern science, driven by the efficiency of neural networks in tasks such as pattern recognition, classification, and visual perception. Neuromorphic computing proposes a paradigm where processing and memory functions coexist within the same structure, overcoming the separation of units typical of conventional architectures. Central to this vision is the development of adaptive, light-responsive materials capable of emulating synaptic plasticity, short- and long-term memory and dynamic nonlinear responses to external stimuli.

In this context, we investigate two complementary material platforms for in-material neuromorphic computing. On one side, we explore the photoactive azopolymer PAZO, a water-soluble and biocompatible system exhibiting optically induced birefringence and spontaneous relaxation.[1] These properties enable synaptic functionalities, including potentiation, relaxation, and the transition from short-term to long-term memory. Benchmark experiments demonstrate the use of PAZO thin films as active reservoirs for pattern recognition tasks, highlighting their potential as intelligent matter for all-optical information processing.

On the other side, we introduce the concept of a 2D memitter based on WS_2 monolayers,[2] exploiting their highly nonlinear and time-dependent photoluminescence (PL) response under optical excitation. The PL dynamics exhibit fading memory effects and synaptic-like behavior, allowing the emulation of biological functionalities such as Visual Short-Term Memory. The scalability and integrability of 2D materials make them promising candidates for next-generation optoelectronic neuromorphic architectures.

By bridging molecular azopolymers and 2D semiconductors, our work underscores the versatility of light-responsive matter as a platform for neuromorphic functionalities and in-material reservoir computing, paving the way for bio-inspired adaptive devices that combine perception, memory, and processing in a single material system.

[1] F. Ferrarese et al. Adv. Mater. 2025, 2501813

[2] F. Ferrarese Lupi et al. Adv. Funct. Mater. 2024, 34, 2403158