

Press Release: 28 January 2026

A Sensor That Sees Like a Retina

Researchers have developed BIOPIX, a retina-inspired biohybrid image sensor array that combines living-like biological liquid environments with organic electronics, advancing artificial vision systems that more closely resemble the way natural eyes work.

January 2026 — A multidisciplinary team of researchers has developed an innovative image sensor that integrates liquid biological environments with organic electronics, mimicking core functions of the animal retina.

Both image photodetector arrays and retinas are pixelated sensors that dynamically extract various features from the visual scene – e.g., color, brightness, and contrast – before transmitting electrical signals to either a graphical interface of a display or the brain. Image sensors rely on solid state semiconductor technology, whereas retinas on photoreceptor cells in water-based ionic environments.

Unlike conventional solid-state image sensor arrays, the device developed by the researchers, named **BIOPIX, operates at the interface between electronics and biology, combining printed organic semiconductor materials with a water-based physiological biological medium.** This integration allows the sensor to capture light through the polymer materials and convert it into electrical signals through the water-based physiological electrolyte **in ways that more closely resemble the phototransduction behavior of natural photoreceptors:** the rods and cones found in the retina of animal eyes.

“We designed this device to go beyond traditional electronic sensors,” explains **Prof. Thomas M. Brown,** at the [Electronic Engineering Department](#) of “Tor Vergata”, coordinator of the research. *“By letting organic electronic materials interact with a liquid biological environment, BIOPIX reacts to light in a way that is much closer to how a real retina works in nature, both in how it senses color (spectrally) and how quickly it responds.”* The temporal response of BIOPIX, on the order of tens of milliseconds, mirrors the slower ionic dynamics of liquid-based mammalian retinas, and its sensitivity is comparable to that of established solid state polymer semiconductor photodetectors.

The array includes 12 pixels that mimic rod-like responses, responsible for low-light and contrast sensitivity, and a central 2×2 array that simulates cone-like di-

chromatic sensitivity for color detection in mice. *"What's exciting about BIOPIX we developed is that when light strikes the liquid/solid bio-hybrid device, it is converted into electrical signals that are processed and displayed as grayscale from the rod-like pixels and color images from the central cone-like pixels in real time on a display"* explains **Ebin Joseph**, PhD student and first author of the article. *"The challenge of converting light incident on BIOPIX into direct-to-display pixelated images was addressed by developing a dedicated electronic readout system tailored to its ionic liquid retina-like temporal dynamics"* added **Dr Luca Di Nunzio**, expert in digital electronics and embedded signal processing both from [Electronic Engineering Department](#) of "Tor Vergata".

Beyond performance, the researchers demonstrated the platform's biocompatibility. *In vitro* tests using human mesenchymal stromal cells showed no adverse effects on cell viability, an important milestone for potential biomedical applications. *"Confirming biocompatibility was a key step,"* said **Prof. Antonella Camaioni** at the [Department of Biomedicine and Prevention of Tor Vergata](#), co-responsible for the research. *"It validates the platform for fundamental research and points toward future possibilities, such as artificial retinal implants or adaptive biointerfaces."*

"Our work represents an important first step toward emulating how the retina forms images, with a long-term goal of developing better retinal prosthetic devices. With BIOPIX, we aim to mimic the spectral and temporal behaviour of the mouse retina, a widely used model for studying degenerative eye diseases, such as retinitis pigmentosa and age-related macular degeneration, that lead to photoreceptor loss and vision impairment." explains **Dr Hiroki Asari**, expert in Visual Systems Neuroscience at [EMBL](#).

The researchers emphasize that BIOPIX is more than a novel sensor: it is a **scalable, versatile platform** for studying how light is converted into electrical signals at the interface of biological and artificial systems. This **retina emulator** platform could aid in the development of artificial photoreceptors, help us better understand the biophysics of phototransduction, natural vision and inspire new technologies in artificial vision and neural interfacing.

Understanding the underlying biophysics, can help in the quest of restoring vision to those who have lost it through degenerative retinal diseases as well as help improve function of the visually impaired.

The Vice President for Research of Tor Vergata University of Rome, **Prof. Massimo Federici**, commented that *"These results highlight the power of*

collaboration, bringing together researchers with assorted expertise, supported by diverse funding programs from our university, as well as local, and international agencies, to tackle complex challenges at the intersection of electronics, biology, bio-physics, engineering, retina neuroscience, and bio-medicine.

Looking ahead, the team sees BIOPIX as a step toward smarter artificial vision and new kinds of technology where light, electronics and biology work together.

*The research, entitled "**A Bio-Electronic Hybrid Solid–Liquid Pixelated Color Image Sensor Array as a Direct-to-Display Artificial Retina Emulator,**" is published in the January 2026 issue of the international journal *Advanced Materials Technologies*, *Adv. Mater. Technol.* 2026, 11, e01461 ([DOI: 10.1002/admt.202501461](https://doi.org/10.1002/admt.202501461)). Inside Back Cover, with conceptual illustration shown below.*

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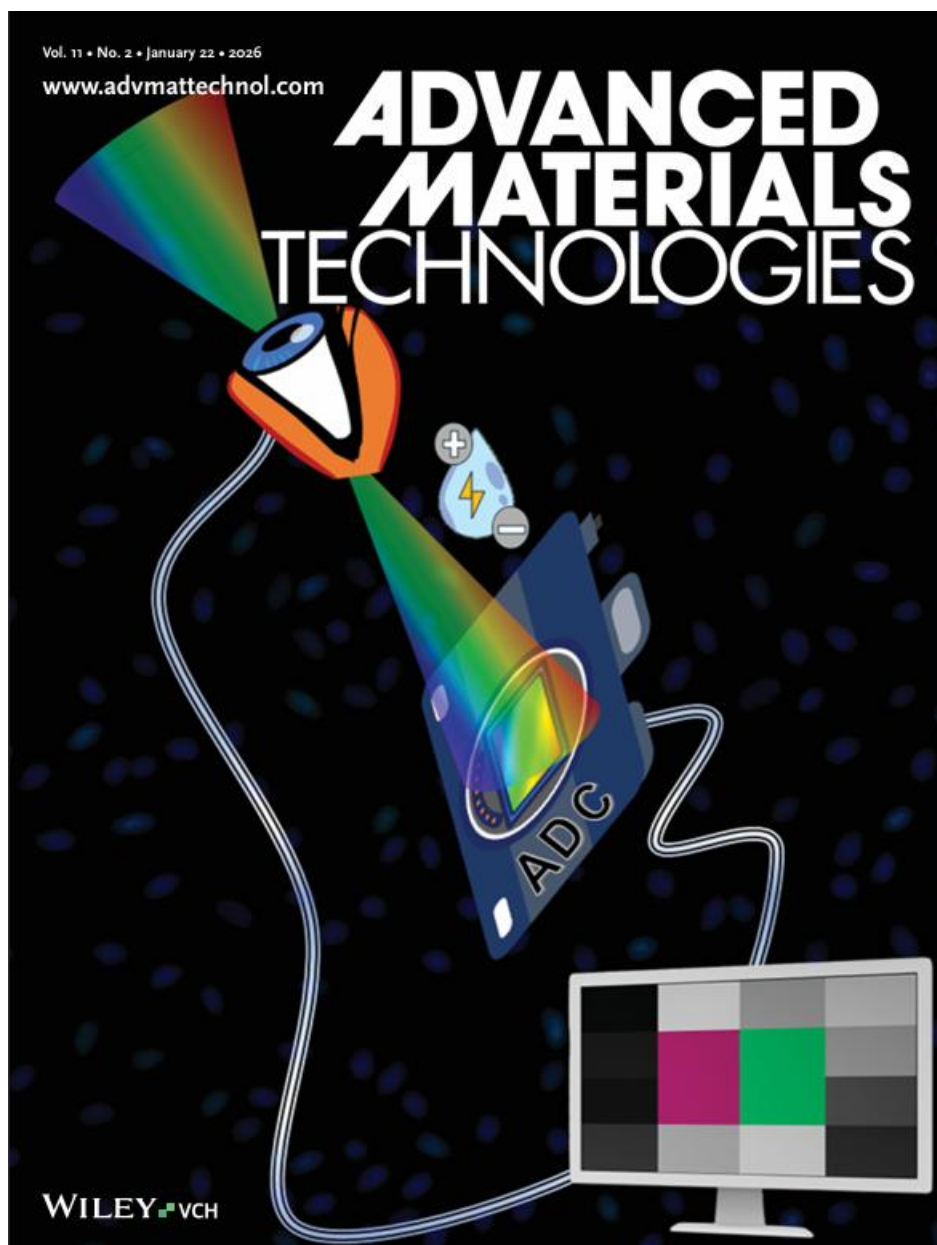
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Research was supported by the Air Force Office of Scientific Research Biophysics Program under Award Nos. FA9550-24-1-0320, FA9550-20-1-0157, and FA9550-25-1-0361; the European Union's Framework Programme for Research and Innovation Horizon Europe (2021–2027) under the Marie Skłodowska-Curie Grant Agreement No. 101068387 (EFESO); Tor Vergata University of Rome for Bando per l'Assegnazione dei Fondi di Ricerca a Gestione Dipartimentale – Dipartimento di Ingegneria Elettronica (ULPC research project, CUP E83C22002660005); and the Lazio Region through the SIROH project "Sight Restoration via Organic and Hybrid Thin Films" (Progetto di Gruppo di Ricerca finanziato ai sensi della L.R. Lazio 13/08 n. 85-2017-15373).

Vol. 11 • No. 2 • January 22 • 2026

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Inside Back Cover: Conceptual illustration of a liquid/solid biohybrid image sensor inspired by animal retinas that integrates organic semiconductors with a liquid retinal physiological medium. The biocompatible 16-pixel array (micrograph of cells cultured over its surface in the background) converts light into ionic–electronic signals, reproducing the spectral/temporal responses of rod/cone photoreceptors of the retina, and generating real-time color/grayscale images on a display through analog-to-digital conversion, thus bridging living and electronic systems.

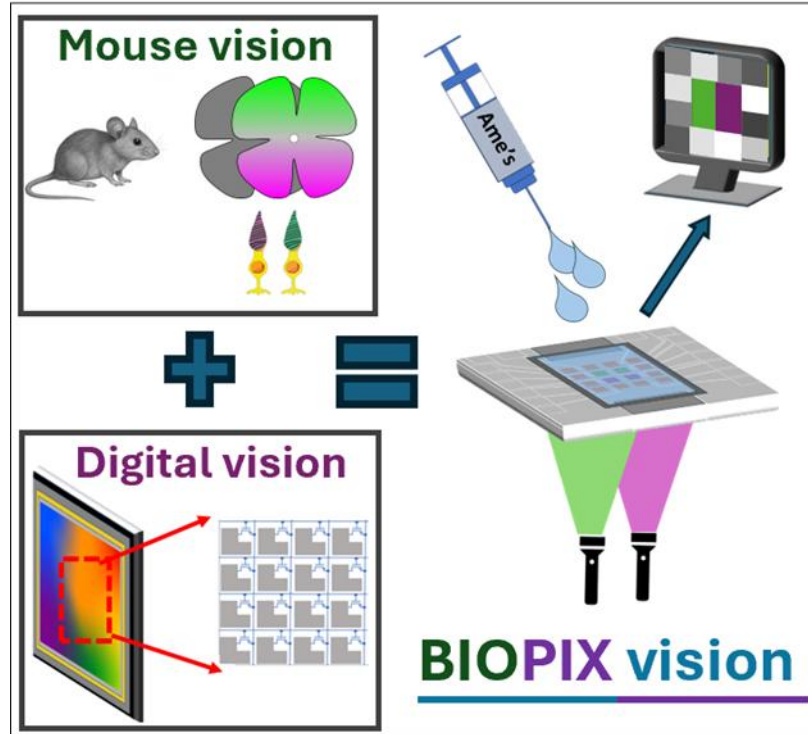


Figure 2: Concept of BIOPIX Vision. A biohybrid color-sensing platform that merges principles of mouse retinal vision (top left) with digital imaging technologies (bottom left). The device integrates polymer-based photodetector pixels with a biological electrolyte (Ames' medium) to emulate cone- and rod-like responses (right), enabling the direct conversion of light into color and grayscale image outputs.

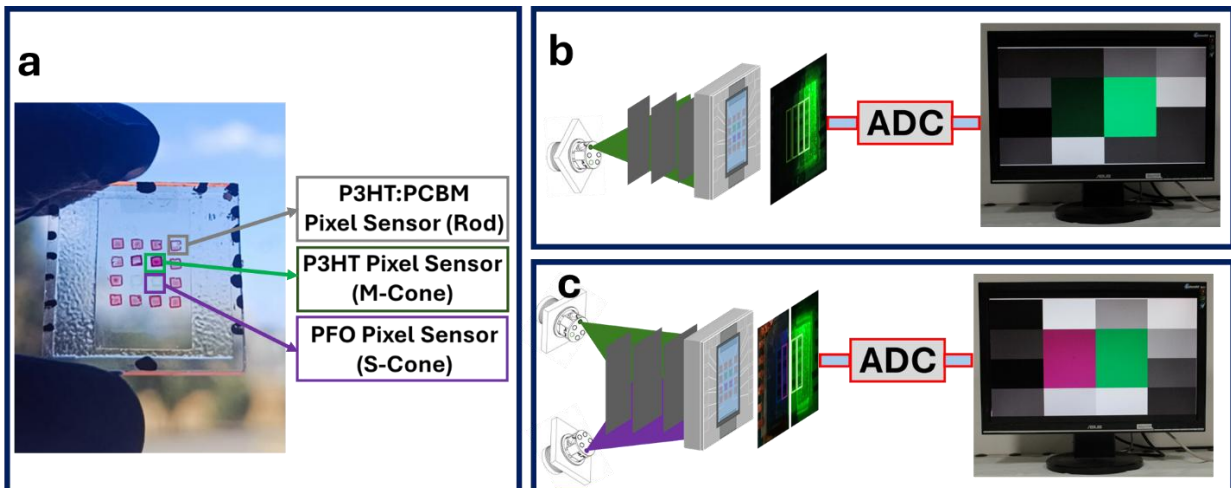


Figure 3: BIOPIX color perception demonstration. a) Photograph of the fabricated multi-pixel biohybrid BIOPIX devices featuring a 16 pixel architecture that mimics rod- and cone-like photoreceptors. b) & c) Experimental setup and digital reconstruction of a grayscale (rod-like artificial photoreception) and color (cone-like photoreception) image obtained when the BIOPIX array was illuminated with green and green plus violet light of increasing intensity and connected to a display monitor via dedicated electronics.