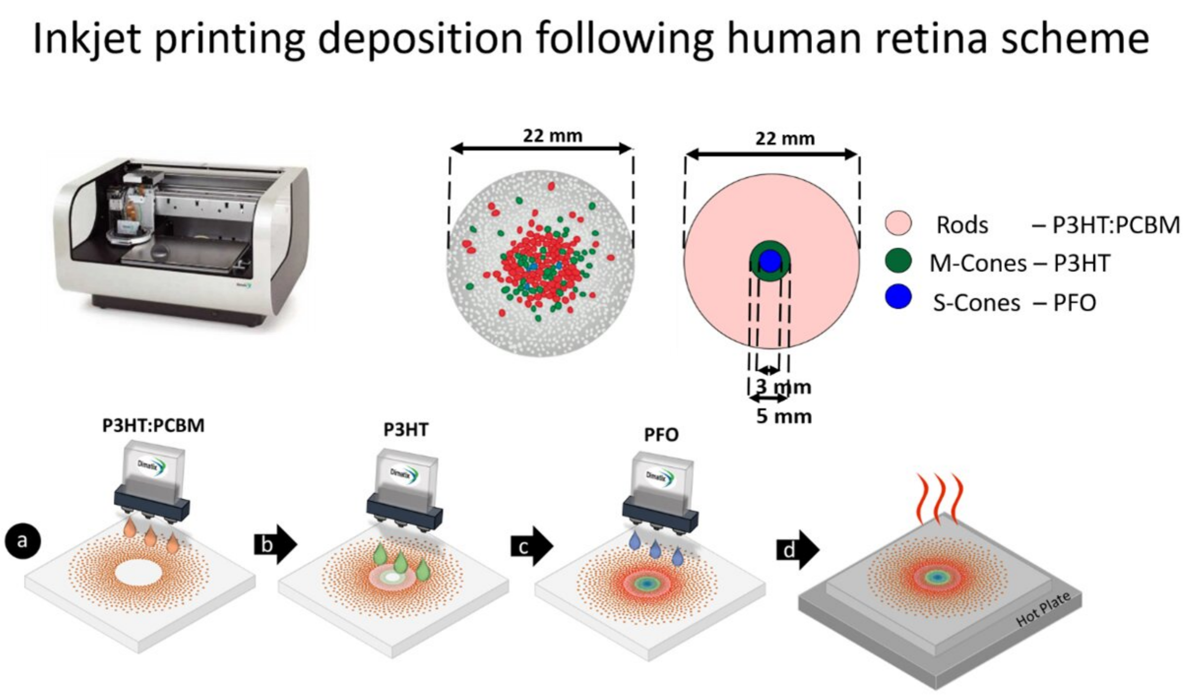
Color-sensitive inkjet-printed pixelated artificial retina based on semiconducting polymers

January 19 2021, by Manuela Ciocca



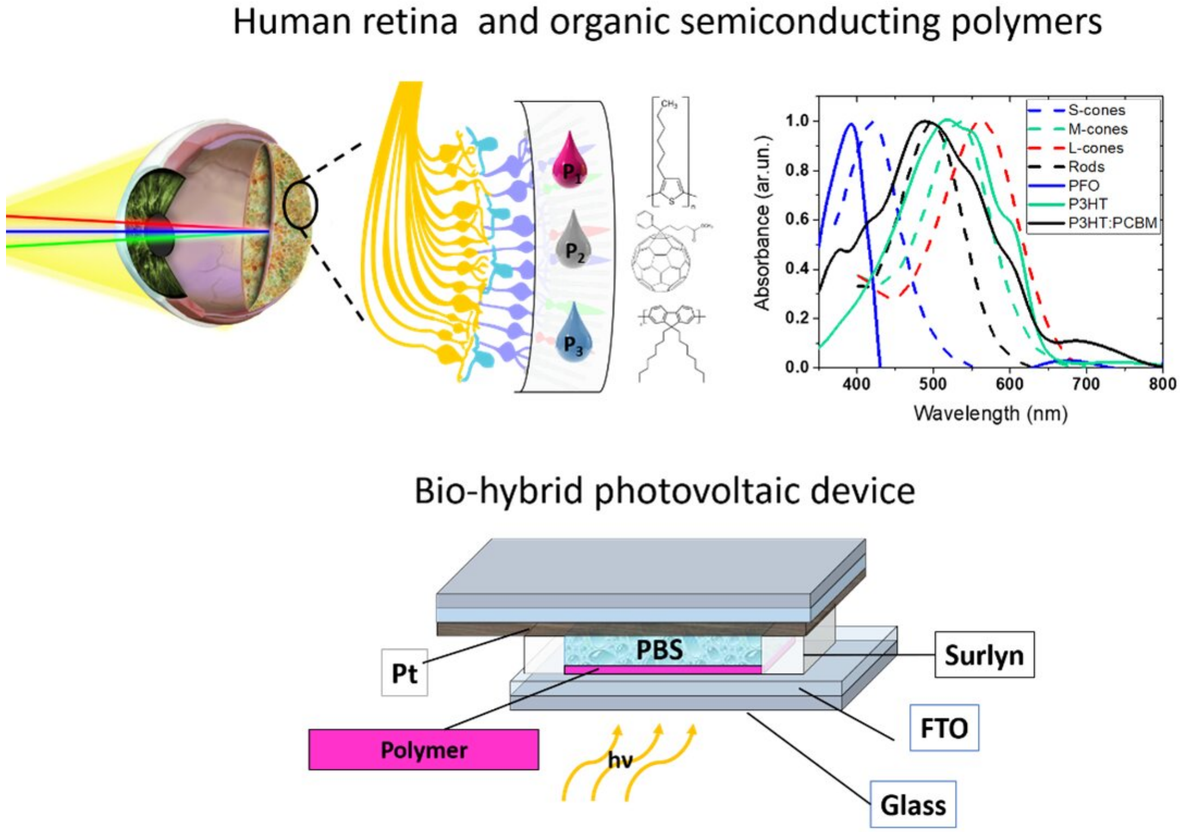
Design and fabrication of a colour-sensitive model of a pixelated artificial retina via inkjet printing. Credit: Manuela Ciocca

Around 300 million people worldwide are visually impaired. Retinitis pigmentosa (RP) and age-related macular degeneration (AMD), involving deterioration of retinal photoreceptor cells, are the leading causes of partial or total loss of vision. In the human eye, the retina contains several layers of cells, including rods and cones, photoreceptors that convert light into electrical signals and are responsible for night and color vision, respectively. With the development of biomedical engineering in recent decades, retinal prostheses designed to partially restore vision have seen progress. However, those based on conventional silicon, metallic or rigid electrodes possess poor flexibility and biocompatibility.

In recent years, photosensitive organic electronic materials have become a promising tool, even transplanted in vivo, for transducing light stimuli to non-functioning retinas. The materials are mechanically flexible and thus applicable to flexible and conformal substrates and can be deposited through inks. Up to now, the spectral responsivity was considered individually for one polymer semiconductor at a time in artificial retina applications. However, restoring color vision requires pixelation of polymers that are photosensitive to different parts of the visible spectrum (color sensitivity).

A multidisciplinary international team with researchers from four research institutes has published the results of their project in an article in *Scientific Reports,* the open access journal from Nature Publishing Group, which highlights the progress made in advancing these goals.

The team members are from University of Rome Tor Vergata (Department of Electronic Engineering and Department of Biomedicine and Prevention), University of Surrey (Department of Electrical and Electronic Engineering, Faculty of Engineering and Physical Sciences, Advanced Technology Institute, Guildford, UK), Istituto di Struttura della Materia (CNR-ISM, Rome, Italy), Cicci Research srl. (Grosseto, Italy), and EMBL (European Molecular Biology Laboratory, Epigenetics and Neurobiology Unit, Monterotondo, Italy).

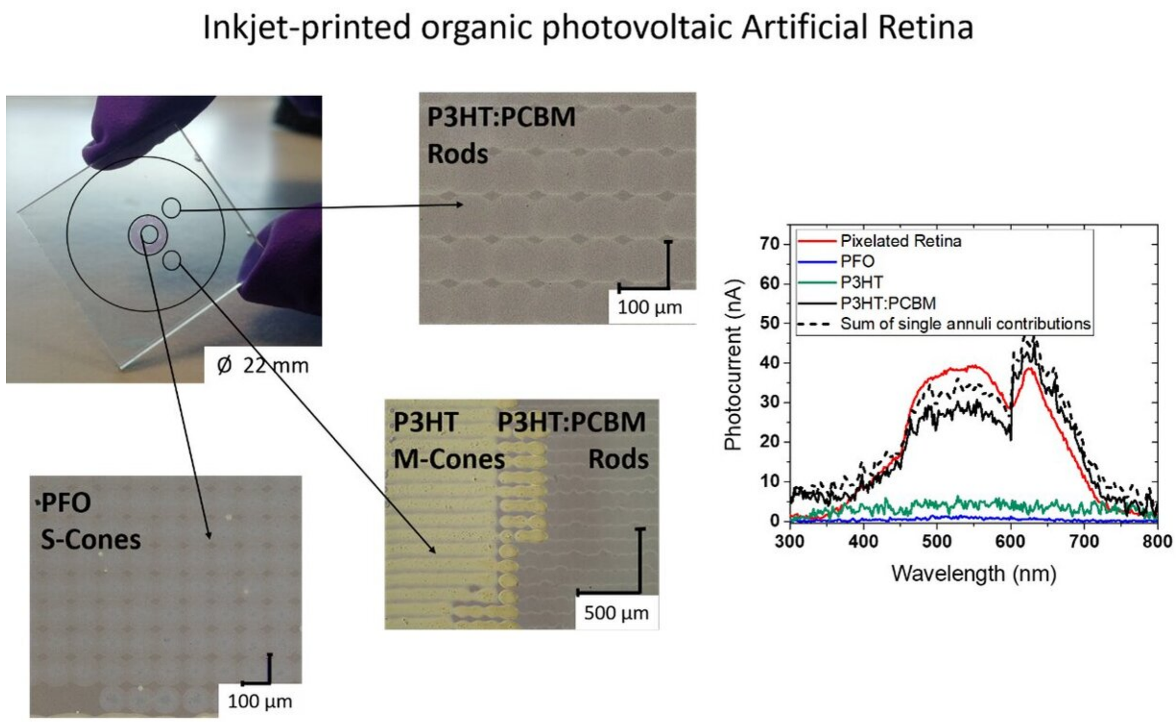


Human retina, organic semiconducting polymers and bio-hybrid photovoltaic device architecture. Credit: Manuela Ciocca

They demonstrate the design and fabrication of a color-sensitive model of a pixelated artificial retina in which each polymer dot was deposited by inkjet printing (Figure 1). Three types of polymer semiconductors with spectral absorbance curves emulating those of rods and cones, which provide color sensitivity, were deposited in a concentric layout, simplifying the anatomical human retinal scheme.

The team verified that the phototransduction process from the artificial retina to a biological electrolyte solution imitating extracellular fluids found in human tissues produced electrical signals compatible with those found in retinas through a novel closed sandwich-type optoelectronic device (Figure 2). The bio-hybrid device, which combines techniques used in electrophysiology, organic photovoltaics and dye-sensitized solar cells, presents some advantages compared to conventional electrophysiological investigative systems: It is compact, easy-to-handle, transportable, compact and requires a small amount of bio-electrolyte, thus permitting use of tools typically used in electronic engineering, physics and chemistry. Photosensing through three-color pixelation allowed incoming light to be resolved both spectrally and spatially. The biocompatibility of each type of photosensitive polymer was also demonstrated.

The artificial retina model with distinct absorption spectra, mimicking the chromatic sensitivity of photoreceptors in the eye and interfaced with a physiological medium has 42,100 pixels; the density of the artificial photoreceptors is ~11,000 pixels/cm^2 and the corresponding spatial resolution is 267 dpi (dots per inch), with pixel diameters of 95 micrometers, comparable to that of a human hair (Figure 3). Future studies should compare and investigate the interaction of the artificial retina model with biological ones. Printing technologies enable placement of materials in the locations of choice.



Microscopy images of the inkjet-printed Artificial Retina and its spectral response. Credit: Manuela Ciocca

In the future of personalized medicine, and with the development of higher resolution techniques (i.e. ≤ 10 micrometers, which is the diameter of human retinal photoreceptors), clinicians may be able to image an individual retina and then print the pixels to reproduce their locations spatially. Moreover, the new device will allow researchers to refine the study of the light signal transduction processes between different photosensitive materials and the liquid bio-electrolyte.

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More information: Manuela Ciocca et al. Colour-sensitive conjugated polymer inkjet-printed pixelated artificial retina model studied via a bio-hybrid photovoltaic device, *Scientific Reports* (2020). DOI: 10.1038/s41598-020-77819-z

Manuela Ciocca is a medical engineer with Ph.D. in electronic engineering-bioelectronics. She worked on development of artificial retinas for sight restoration using organic polymeric thin films. She won the ITWIIN (Italian Women Inventor&Innovator) Awards-Special Mention; MaterialConneXion-Best Innovative woman 2016, and the EIWIIN (European International Women Inventors&Innovators) Special Recognition Award 2017 for ingenious and innovative achievements.