

Bionic Eyes

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Using space technology, scientists have developed extraordinary ceramic photocells that could repair malfunctioning human eyes.

Millions of rods and cones are in the back of every healthy human eye. They are biological solar cells in the retina that convert light to electrical impulses – impulses that travel along the optic nerve to the brain where images are formed. Without them, we're blind.

Many people are blind – or going blind – because of malfunctioning rods and cones. Retinitis pigmentosa and macular degeneration are examples of two such disorders.

There are some diseases where the sensors in the eye, the rods and cones, have deteriorated, but all the wiring is still in place. In such cases, thin-film ceramic sensors could serve as substitutes for bad rods and cones. The result would be a "Bionic Eye."

Preliminary tests conducted on the ceramic detectors for biocompatibility appear to be totally stable. The detectors do not deteriorate and neither does the eye.

Ceramic detectors are thin films, grown atom-by-atom and layer-by-layer on a background substrate – a technique called epitaxy. This method produces the best optical properties.

The detector currently under development is a thin-film ferroelectric detector. Under optical illumination, it can generate a local photocurrent and photovoltage. The local electric current generated by this miniature detector excites the retinal neural circuit resulting in a signal at the optic nerve that may be translated by the cortex of the brain as "seeing light." Detectors based on PbLaZrTiO_3 (PLZT) and BiVMnO_3 (BVMO) films exhibit a strong photo response in visible range overlapping eye response from 380 nm to 650 nm.

The ceramic detectors are much like ultra-thin films found in modern computer chips. We can use our semiconductor expertise and make them in arrays – like chips in a computer factory. The arrays are stacked in a hexagonal structure mimicking the arrangement of the rods and cones that they are designed to replace.

The natural layout of the detectors solves another problem that plagued earlier silicon research: blockage of nutrient flow to the eye. The ceramic detectors are individual, five-micron-size units (the exact size of cones) that allow nutrients to flow around them. Artificial retinas consist of 100,000 tiny ceramic detectors, each 1/20 the size of a human hair. The assemblage is so small that surgeons can't safely handle it. The arrays are attached to a polymer film one millimeter by one millimeter in size. A few weeks after insertion into an eyeball, the polymer film will simply dissolve leaving only the array behind.

These first-generation ceramic thin-film micro detectors, each about 30 microns in size, are attached to a polymer carrier, which helps surgeons handle them. The image shows human cones 5-10 microns in size in a hexagonal array.

Scientists aren't yet certain how the brain will interpret unfamiliar voltages from the artificial rods and cones. They believe the brain will eventually adapt although a slow learning process might be necessary – something akin to the way an infant learns shapes and colors for the first time.

Thin-film detector heterostructures have been implanted into the eyes of rabbits for biocompatibility tests, and have shown no biological incompatibilities. Optical response tests are in progress.

Though the bionic eye is still at least five years away by most estimates, experts are nevertheless hopeful. While good progress is being made on the retinal chip implant, it is not clear if this approach will finally work.

References

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