AlGaAs/GaAs Heterojunction Prosthetic Retina

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Abstract:

Diseases such as retinitis pigmentosa and age-related macular degeneration lead to gradual loss of eyesight due to the progressive loss of retinal photoreceptors. Currently, several treatments for these diseases are being used to slow vision loss. One in particular hopes to restore partial vision by implanting an artificial retina using solar cells to provide electrical stimulation of the ganglion cells of the eye when exposed to light.

The objective of this work was to fabricate an AlGaAs/GaAs prosthetic retina with an array of 10 μm diameter solar cells on a 3 x 3 mm^2 chip. Open circuit voltages of 0.82V were obtained under illumination for these cells. Mesas were etched into both sides of this chip to minimize electrical crosstalk between cells and minimize movement of the chip once implanted.

Introduction:

Once light enters the eye, it stimulates the retina's rods and cones. These are photoreceptors which are responsible for detail, low light and color vision. This light is then converted into electrical signals which are sent to the brain, via the optic nerve, and interpreted as vision. There are several retinal diseases such as retinitis pigmentosa (RP) and age related macular degeneration (AMD) which disrupt the normal functions of the eye, more specifically the retina. RP is a genetic disorder which causes abnormalities of the retina's photoreceptors. AMD is a disease which causes loss of the sharp central vision needed to read or drive.

Since RP and AMP affect millions of people worldwide, strides are being made to slow down or stop their progression. Many researchers and practitioners believe that administering beta carotene (vitamin A), vitamins C, E and other nutrients can lower the risk of developing or slow down the progression of particular retinal diseases. There are also many FDA-approved drugs such as Macugen® and Visudyne® that are used with

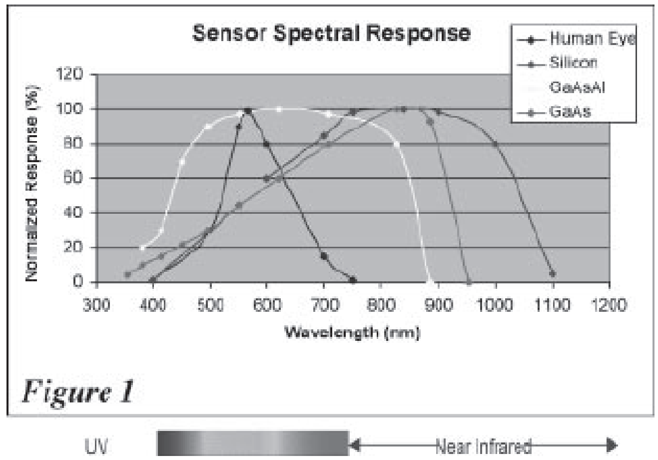

Figure 1

photodynamic therapy (PDT) to treat patients. Lastly, many labs are developing artificial retinal implants (prosthetic retinas) to restore vision to patients. One very promising type of implant utilizes solar cell technology to provide electrical stimulation to the retina.

Many researchers, like those at Optobionics, are using silicon (Si) to make solar cell implants. Though silicon-based implants have several advantages, GaAs-based solar cells are more efficient. By adding aluminum to GaAs, the spectral response can be tuned to resemble that of the human eye (Figure 1). A thin layer of AlGaAs near the surface helps to decrease surface recombination while serving as a window allowing light to penetrate other regions of the cell.

Experiment:

The fabrication of the prosthetic retina began with the growth of GaAs and AlGaAs layers by molecular beam epitaxial (MBE) on a 100 μm thick n+ GaAs wafer. The first layer was a n+ GaAs buffer layer followed by a lower doped n+ GaAs layer. The third layer grown was p+ GaAs in order to create a p-n junction needed to power the cell. Next, a thin layer of p+ AlGaAs was grown and followed by a very thin cap layer of p+ GaAs. All n-type and p-type layers were doped with silicon and beryllium respectively.

After growth, metal contacts were evaporated onto both sides of part of the wafer to test for cell efficiency. The bottom n-type contact was 20 nm of germanium : 20 nm of nickel : 200 nm of gold. The top p-type contact, which were 10 nm wide fingers, were 40 nm of titanium : 30 nm of platinum: 100 nm of gold. The contacts were then alloyed at 450ºC for 1 min. Electrical measurements indicated a short circuit current of 2.1 mA and an open circuit voltage of 0.82V. The fill factor was calculated to be 0.52 and the solar cell efficiency was 5%. Fabrication of the prosthetic retina also involved making contacts to both sides. The bottom side contact was the same as mentioned above while the top contact was a 7 nm thick layer of gold. The top contact was made semi-transparent to allow light to penetrate the cell.

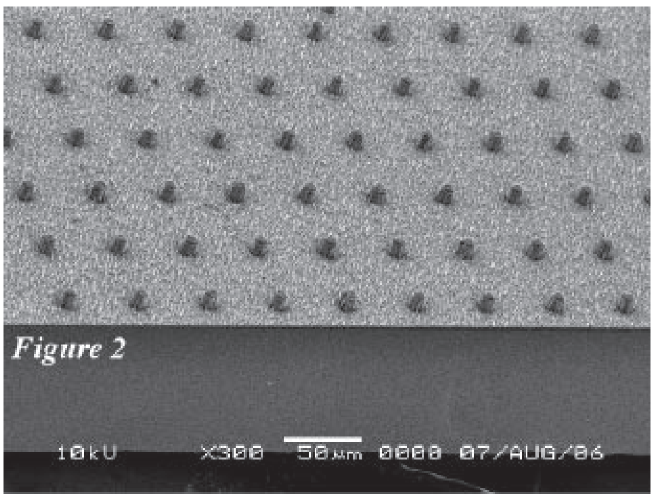

Figure 2

The next step was to form mesas on the top surface by reactive ion etching (RIE). The area that was not etched (an array 10 μm diameter cells with a 50 μm pitch) was masked with either a thick photoresist or metal layer by photolithography. The device was then exposed to 15 sccms of Cl_2 at a pressure of 15 mtorr and 225 watts of RF power for 30 minutes. These conditions produced a mesa depth of approximately 10 μm with vertical sidewalls (Figure 2). After RIE, any remaining photoresist or metal mask was removed and the sample alloyed at 450°C to form ohmic contacts.

The final prosthetic retina was 2.5 mm^2 in size and consisted of roughly 1900 solar cells and is shown in Figure 3 next to a dime to provide a size comparison.

Results and Discussion:

Previously, solar cells made from epilayer structures similar to the one used in this work had yielded efficiencies as high as 20%. The 5% obtained in this work is well below what was expected. The reason for this low efficiency is not known. The good news is that a high open circuit voltage of 0.82V was obtained for this structure. It should be noted that the efficiency of the final prosthetic device could not be measured because the 10 μm cells were too small to contact.

In the future, RIE conditions need to be optimized to allow deeper and cleaner mesas. The AlGaAs/GaAs epilayer structure needs to be optimized to produce a higher efficiency. Redesign of the retina mask should also be done to more closely simulate the natural eye retinal geometry. Finally, an encapsulating layer will need to be developed before the device can implanted into the eye.

Acknowledgements:

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Figure 3