Fabrication and Characterization of $Mg_xZn_{1-x}O$ Based UV Photodetectors

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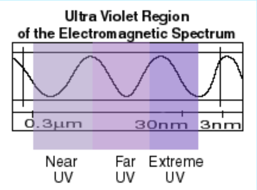
ULTRA VIOLET RADIATION

Ultraviolet light is electromagnetic radiation at wavelengths shorter than the violet end of visible light. It has 3 specific classifications:

- •UVA (100nm – 280nm)
- •UVB (280nm – 315nm)
- •UVC (315nm – 400nm)

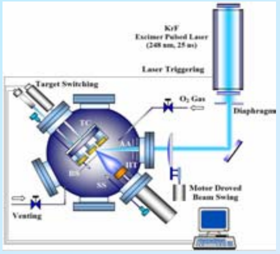


FAVORABLE QUALITIES OF MgZnO FOR UV DETECTION

The band-gap of a material is the energy difference between the valence band and conduction band. The larger the band-gap, the more energy is required to move an electron from the valence band to the conduction band. The band-gap of UV light is between **3.1eV to 12.4eV**. Adjusting the ratio of Magnesium and Zinc in $\mathbf{Mg_xZn_{1-x}O}$ can account for this band-gap. UV light excites devices made from $\mathbf{Mg_xZn_{1-x}O}$ when they fall on it. This principal can be used for UV detection.

FILM GROWTH

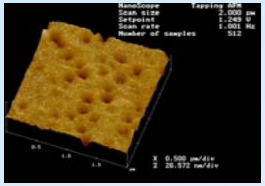
Pulsed Laser Deposition (PLD) was used to deposit the $Mg_xZn_{1-x}O$ films on sapphire (Al_2O_3) substrates. This method of deposition involves directing a laser beam pulse onto target of the substance to be deposited, in this case some composition of $Mg_xZn_{1-x}O$. The high energy in the laser beam ejects a plume of the substance from the surface of the target. The desired substrate is placed on a heating surface and properly aligned to be at

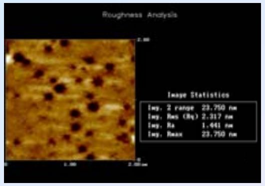


the direct center of the plume. The heating of the substrate is to allow better adhesion and to make it easier for the target material to crystallize on the surface. The number and energy of the laser pulses along with the sticking coefficient of the target material determine the eventual thickness of the film.

SURFACE CHARACTERIZATION

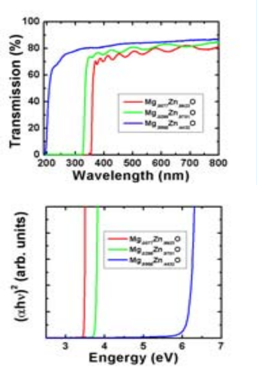
An Atomic Force Microscope (AFM) was used to measure the roughness and determine the structure of the film. The hexagonal structure of MgZnO can be seen in the pictures below.





OPTICAL CHARACTERIZATION

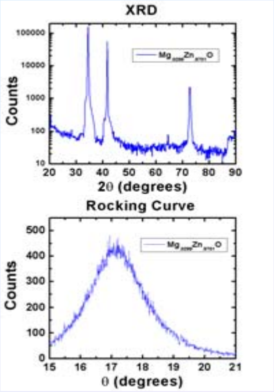
The optical properties of the MgZnO films were analyzed using UV-visible spectroscopy. The film was designed to absorb certain wavelengths of light and is therefore transparent at these wavelengths. The photons with energy equal to or greater than the band-gap of the material get absorbed when they excite electrons from the valence band to the conduction band. Photons at lower energy levels don't excite electrons and hence pass freely through the material. The optical response is measured by shining an adjustable monochromatic light source through the substance and measuring the intensity passed through. The light source steps through the UV and visible spectrum of light, collecting a measurement for each wavelength.



The band gap of the material can be measured by analyzing the wavelengths of light that are absorbed. For example, in the above graphs the composition $Mg_{0.5568}Zn_{0.4432}O$ does not absorb light with wavelength greater than 400 nanometers. Therefore, MgZnO photodetectors are visible-blind. For certain applications, this is a distinct advantage over other semiconductor materials, such as silicon, that can catch visible light when only ultra-violet light detection is intended.

STRUCTURAL CHARACTERIZATION

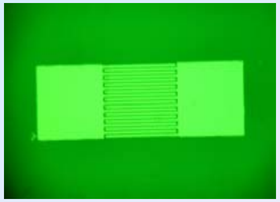
X-Ray Diffraction (XRD) or Bragg diffraction is performed by bombarding a substance with x-rays. These rays are scattered by the atoms in the substance. If the substance has a crystalline structure then the rays will be scattered at a specific angle. This angle is determined by the type and



alignment of the crystalline structure. Therefore by measuring the number of rays scattered at each angle, the corresponding crystal structure can be determined. The peaks shown in the figure correspond to two different crystalline states of the MgZnO (the two outer peaks) and the crystalline structure of the sapphire substrate (center peak). "Rocking Curve" measurements are a specific type of XRD taken by slightly tilting the substance as it is subjected to the x-rays. This rounds off peaks because the crystal structure is no longer stationary and will now deflect the x-rays at slightly different angles depending on the tilt. A narrow rocking curve, like the one in the figure, shows a high quality of crystal

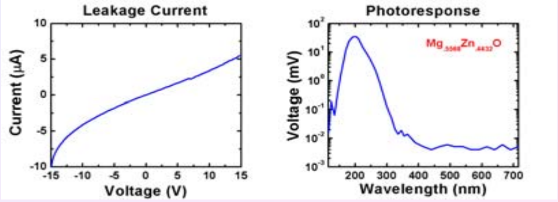
DEVICE FABRICATION

The device fabrication on MgZnO film was done using a standard process of photolithography with positive photoresist, S1813. The exposure time for the sample varied between 25 seconds and 35 seconds depending on the thickness of the sample. The sample was then soaked in chlorobenzene and oven baked to deepen the wells after exposure for better metallization. The sample was developed using AZ400K developer. The thermal evaporator was used to deposit a layer of chrome and then a second layer of gold. After metallization, the sample was soaked in acetone for liftoff.



DEVICE TESTING

The devices produced from the above fabrication process were first I-V characterized in order to determine their leakage current. If leakage current was too high there was commonly a short somewhere in the device and therefore the device was discarded. Lower leakage currents and an ohmic (linear) response were desired. The devices with such I-V responses were tested for their photoresponse, which shows the output of the device when subject to light across the spectrum. The response graph below shows the behavior of the device when subjected to light from the UV region. Different MgZnO compositions will have varied photoresponse peaks across the UV spectrum.



CONCLUSIONS

$Mg_xZn_{1-x}O$ is a good material for UV photo detection. By varying the composition of Mg, this material can be used to detect the whole UV spectrum. Detectors built with $Mg_xZn_{1-x}O$ have tremendous potential for applications such as UV astronomy, satellite communications, medical applications, and ozone whole monitoring. A good area for future research on these devices would be coating these detectors with radiation hard protective materials like diamond films that can make them suitable for use in hostile environments like space. Lastly, we thank University of Maryland, Blue Wave Semiconductors, and the National Science Foundation for providing us with this opportunity.