L.11: Development of visible blind UV photodetectors based on $Mg_xZn_{1-x}O$ thin films

Visible blind UV photodetectors are important for multiple applications such as arc flash, flame and combustion monitoring, environmental monitoring, and industrial quality control, etc. Among various wide bandgap semiconductors, $Mg_xZn_{1-x}O$ is considered promising owing to its large tuneable bandgap from ~3.4 to 7.7 eV, radiation and thermal stability, low cost, and environment friendliness.

Visible blind UV photodetectors using $Mg_xZn_{1-x}O$ thin film have been developed. The $Mg_{0.15}Zn_{0.85}O$ thin film based metal-semiconductor-metal (MSM) devices with interdigitated metal (Al and Pt) electrodes were fabricated in-house. The interdigital electrodes were grown on glass substrates by RF sputtering using a marker pen approach. The digit spacing was ~ 250 µm and the digit width and length were ~ 500 µm and 5000 µm, respectively. About 100 nm thick $Mg_{0.15}Zn_{0.85}O$ film was then deposited over interdigitated metal electrodes using pulsed laser deposition to fabricate planer MSM devices. The as grown $Mg_{0.15}Zn_{0.85}O$ thin film showed bandgap of ~3.6 eV. After the deposition of $Mg_{0.15}Zn_{0.85}O$ film, a capping layer of ~90 nm thick MgO film was deposited in-situ on top of it to improve the device stability. The schematic of device top and cross-sectional views are shown in Figure L.11.1.

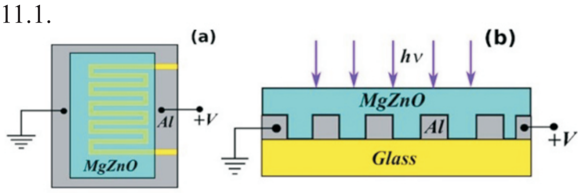

Fig. L.11.1: Schematic illustration of (a) cross-sectional, and, (b) top view of the device.

A Keithley make SMU 2450 was used for electrical and spectral responsivity measurements while a xenon lamp coupled with 1/4-meter monochromator was used for illuminating the devices. The temporal response was measured by exposing the device with a 20 ns excimer laser pulse at 248 nm wavelength and recording the current as a function of time. The typical spectral responsivity and temporal response of $Mg_{0.15}Zn_{0.85}O$ based MSM is shown in Figure L.11.2. The optimized $Mg_{0.15}Zn_{0.85}O$ MSM UV photodetectors showed following characteristics:

1. UV to visible rejection ratio ~ 2.7×10^4
2. Responsivity ~ 20 mA/W at 310 nm
3. ON/OFF ratio $\geq 10^2$
4. Cut-off wavelength ~ 350 nm
5. Photocurrent rise and fall time ~ 400 ns and 139 µs (measured using 20 ns laser pulse)

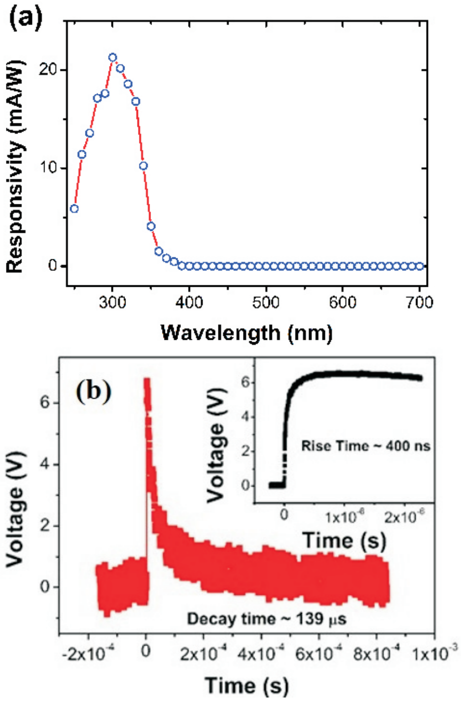

Fig. L.11.2: (a) Spcetral responsivity, and, (b) temporal response of $Mg_{0.15}Zn_{0.85}O$ MSM UV photodetectors following a 20 ns laser pulse at 248 nm.

The $Mg_xZn_{1-x}O$ based visible blind UV photodetectors have been successfully utilized to develop a prototype version of hand-held arc-flash and fire/flame detector. The in-house developed arc-flash and fire/flame detector consists of an excitation circuit, precision amplifier, voltage comparator, and digital logic circuit with buzzer (Figure L.11.3). The excitation circuit provides 5 V stable bias to the $Mg_{0.15}Zn_{0.85}O$ MSM UV photodetector, which on exposure to UV radiation emanating from arc-flash or flame results in rapid increase in current through it. This change in current is converted to amplified voltage by a precision amplifier and the output is compared with a known threshold voltage by a comparator. The comparator triggers a logic circuit to activate the alarm. In addition, the output of detector can also be used to shut down electrical systems by detecting UV radiation of arc-flash prior to the spread of fire.

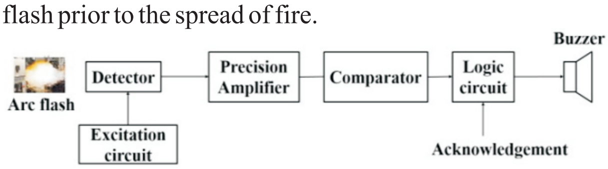

Fig. L.11.3: Block diagram of visible-blind arc-flash detection system.

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