Polarization sensitive solar-blind detector based on $\alpha$-plane AlGaN.

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Abstract

We report polarization-sensitive solar-blind metal-semiconductor-metal UV photodetectors based on (1120) $\alpha$-plane AlGaN. The epilayer shows anisotropic optical properties confirmed by polarization-resolved transmission and photocurrent measurements, in good agreement with band structure calculations.

Solar blind UV (SBUV) detectors, with no photosensitivity above 280nm wavelength, have wide range of applications like – missile plume detection, UV astronomy, chemical/biological battlefield reagent detection etc.\textsuperscript{1–3}. The wide-bandgap, high-temperature compatible AlGaN material system has been the workhorse for such SBUV detectors with many reports on high performance devices based on [0001] $c$-plane AlGaN layers. The inherent anisotropic optical properties and reduced crystal plane symmetry of “non-polar” (1120) $\alpha$-plane AlGaN epilayers allows the fabrication of polarization sensitive (PS) detectors. Such PS detectors give additional advantages of selectivity and narrow band detection in a differential configuration consisting of two or four photo-detectors, without using filters\textsuperscript{4,5}. We present, to the best of our knowledge, the first report of a PS SBUV detector.

About 0.5$\mu$m thick Al$_{0.6}$Ga$_{0.4}$N epilayers were grown on AlN buffer layers via metal organic vapour phase epitaxy (MOVPE) in a closed-coupled showerhead reactor using standard precursors. The details of the growth procedure, method to estimate the solid phase Al content and strain in the layer can be found in Refs.[6,7]. Metal-Semiconductor-Metal (MSM) type devices with interdigitated finger geometry Schottky contacts (metallization–200Å Ni/1000ÅAu) were fabricated using standard optical photolithography, electron-beam evaporation and lift-off techniques.

The III-nitride semiconductors have three closely-spaced valence bands near the center of $k$-space.

Figure 1: (a) Schematic diagram showing the three closely spaced valence band at $k$=0 of the III-nitrides. (b) Orientation of hexagonal unit cell for $\alpha$-plane nitrides. The in-plane strains are $\epsilon_{yy}$ and $\epsilon_{zz}$.
Figure 2: (a) Optical absorption spectra of $a$-plane Al$_{0.6}$Ga$_{0.4}$N showing difference in bandgap $E_4=60$ meV for two different polarizations. Inset: calculated $E_4$ as a function of in-plane strains, black dot represent the strain in our layer for which the calculated value is $\sim 80$ meV (b) Polarization resolved photocurrent measurement for $E \parallel c$ and $E \perp c$ polarization, confirming polarization sensitivity with sharp cut-off below 280 nm. Inset: different in responsivity as a function of wavelength.

the Brillouin-zone ($k=0$) as shown in Fig.1(a). The transition probabilities of electrons from each valence band to the conduction band are different and are strongly determined by the polarization of light. For (1120) $a$-plane epilayers, the in-plane strains are $\epsilon_{yy}$ and $\epsilon_{zz}$ as shown in Fig.1(b). Using HRXRD we estimate the in-plane anisotropic strain in our Al$_{0.6}$Ga$_{0.4}$N epilayer as $\epsilon_{yy}=-0.5\%$ and $\epsilon_{zz}=+0.2\%$, for which $E1$ transition is strongly $z$-polarized and $E2$ transition is strongly $y$-polarized, obtained from the band structure calculation by solving the Bir-Pikus Hamiltonian $^8$.$^9$.

Fig.2(a) shows the absorption spectra of Al$_{0.6}$Ga$_{0.4}$N for two different polarizations, where the extrapolation of $\alpha^2$ vs. energy plot gives the bandgaps of the epilayer as $\sim 4.67$ eV and $\sim 4.73$ eV for $E \parallel c$ and $E \perp c$ polarization directions respectively. So the valance band splitting $E_4=E2-E1$ is $\approx 60$ meV. Fig.2 (a) inset shows the calculated $E_4$ as a function of in-plane strain and the the black dot represents the strain in the layer. The experimentally obtained value of $E_4$ fairly matches with the value 80 meV obtained from calculation.

The polarization-resolved photocurrent measurement on the device (geometry: finger width 10$\mu$m and gap 10$\mu$m; bias voltage=10 V) fabricated on Al$_{0.6}$Ga$_{0.4}$N shows different responsivity spectra $Rc$ and $Rm$ for different in-plane polarization $E \parallel c$ and $E \perp c$ respectively, as shown in Fig.2(b). Inset shows the difference in responsivity ($Rc - Rm$) as a function of wavelength. It shows a peak at $\sim 265$ nm with peak responsivity of $\sim 15\%$ to the maximum responsivity $Rc$ and FWHM of $\sim 10$nm. The UV to visible rejection ratio is $10^2$. The polarization sensitivity contrast ($Rc/Rm$) is about 1.2. Both the spectra shows cut-off below 280nm, fulfilling the solar-blind criteria, and making this perhaps the first demonstration polarization sensitive SBUV detectors reported so far.

In conclusion, we have successfully demonstrated polarization-sensitive SBUV detectors fabricated on non-polar $a$-plane AlGaN. Such devices will be helpful for civil and strategic applications.

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