In this data article, the properties of all transparent metal oxide of ZnO/NiO heterostructure “Transparent all-oxide photovoltaics and broadband high-speed energy-efficient optoelectronics” [1] are presented by characteristics of ZnO and NiO layers, open circuit voltage decay (OCVD), broadband light with intensity dependent current-voltage plots. The device performances under the effect of various optical excitation of intermediated-band, bound excitonic, free-excitonic and band-to-band are presented. The ZnO/NiO heterostructure direction grown on ITO/glass substrate by large area sputtering method [1] was characterized by UV–visible plots and scanning electron microscope (SEM). Carrier lifetime using OCVD of ZnO/NiO devices with carbon paint metal contact is presented. Prolonged open circuit voltage plots under UV light intensity are shown for stability and repeatability studies. I–V characteristics of ZnO/NiO heterostructure under the light wavelength from 623 nm to 365 nm are presented for energy efficient broadband optoelectronics.

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1. Data

Fig. 1 shows the large area samples of ZnO/NiO heterostructure grown at room temperature using by 4-inch sputtering [1]. The transmittance, reflectance, absorption coefficient and Tauc plot data of NiO, ZnO, and ZnO/NiO films on the ITO/glass are presented in Fig. 2. Further, the cross-sectional and surface morphology of the ZnO/NiO heterostructure is presented in Fig. 3 by using FESEM images. Estimated carrier lifetime of ZnO/NiO device from OCVD plots is shown in Fig. 4. Fig. 5 shows the solar cell performances. The light source of the wavelength of 385 nm was used to acquire these data. Fig. 6 shows the I–V characteristics plots of ZnO/NiO device under various wavelength of light illumination and its intensity dependent. Intermediated-band optical excitation induced I–V characteristics are shown in Fig. 6 a–c for the light wavelength of 623 nm, 520 nm, and 460 nm, respectively. Bound-excitonic optical transition induced I–V plots are shown in Fig. 6d and e for the light wavelength of 410 nm and 400 nm, respectively, while free-excitonic induced I–V plots are shown in Fig. 6f. Band-to-band optical excitation induced I–V plots are shown in Fig. 6g for the light wavelength of 365 nm.
Fig. 1. Large-area ZnO/NiO samples on ITO-coated glass. The yellow area is masked using Kapton tape. The reference samples of ZnO and NiO are prepared on the ITO/glass substrate.

Fig. 2. (a) Transmittance, (b) reflectance and (c) absorption coefficient of NiO, ZnO, and ZnO/NiO fabricated on ITO/glass. Tauc plot analysis: (d) ZnO, (e) NiO, and (f) ZnO/NiO samples on ITO/glass. Here, \( \alpha (\lambda) = \frac{1}{\varepsilon} \ln \left( \frac{1-R(\lambda)^{1/2}}{T(\lambda)^{1/2}} \right) \), where \( \varepsilon \) is the film thickness.
2. Experimental design, materials, and methods

2.1. Sample preparation

The eagle glass was used as the substrate for the ITO/ZnO/NiO device fabrication and was cleaned prior to the fabrication process described in Ref. [1].

Fig. 3. Cross-sectional images of (a) glass/ITO/ZnO/NiO, (b) glass/ITO/ZnO/NiO/Ni (sputtered), and (c) glass/ITO/ZnO/NiO/Ag paste. The device schematic is shown on the right of each FESEM image. Surface morphology of the device (d) before and (e) after Ni deposition using sputtering.
2.2. Sample characterization

Samples of ZnO/NiO characterized in this data article are shown in Fig. 1. The transmittance, reflectance data of NiO, ZnO, and ZnO/NiO samples obtained using UV–visible diffused reflectance photometer are presented by Fig. 2a and b, respectively. Diffused integrating sphere was used to mount the samples. The absorption coefficient data of these samples are presented in Fig. 2c and their Tauc plots for the direct allowed optical transition are shown in Fig. 2d–f. The thickness of the device was measured from the cross-sectional images as shown in Fig. 3a–c, while the surface morphology of the device before and after Ni layer deposition is shown in Fig. 3d and e, respectively. These images were obtained by Field emission scanning electron microscope (FESEM, JOEL, JSM_7800 F). Carrier lifetime of the ZnO/NiO device was studied by OCVD analysis as shown in Fig. 4. These plots were obtained from the device with carbon paint under the pulsed light illumination of 385 nm and intensity of \(10^{20}\) mW/cm². A function generator (MFG-3013A, MCH instruments) was applied to control the pulse rate and the light intensity. Stability, repeatability, and effect of UV light intensity of the fabricated ITO/ZnO/NiO/Ag microink device were studied by the prolonged VOC characteristics as shown in Fig. 5. These data were obtained under the UV light wavelength of 385 nm with the intensity of \(10–20\) mW/cm². I–V characteristics of the ZnO/NiO/Ag microink device under the various optical excitation in steady-state are shown in Fig. 6. The light wavelength of 623 nm, 520 nm, and 460 nm was used to obtain the intermediate-band optical excitation induced I–V plots as shown in Fig. 6a–c, respectively. Light wavelength of 410 nm and 400 nm was used to obtain the I–V plots from bound-excitonic optical excitation as shown in Fig. 6d and e, respectively. Further, the free-excitonic optical induced I–V plots obtained using a wavelength of 385 nm are shown in Fig. 6f. Finally, 365 nm wavelength of light was used to obtain the band-to-band optical excitation induced I–V plots as shown in Fig. 6g.

2.3. Carrier lifetime using open circuit voltage decay (OCVD)

The \(V_{OC}\) in a conventional solar cell is defined as the difference between the quasi-Fermi levels of electrons \(E_{fn}\) and holes \(E_{fp}\) at the respective selective contacts (ITO and NiO/Metal choice) (reference [3,4]).

\[
qV_{OC} = E_{fn} - E_{fp}
\]
where q, $E_{fn}$ and $E_{fp}$ are the elementary charge and the quasi-Fermi levels corresponding to the electrons and holes, respectively. This means that the $V_{OC}$ value resides between the conduction band ($E_c$) and the valence band ($E_v$). The separation of quasi-Fermi levels corresponding to the photogenerated electrons ($n$) and holes ($p$) is fundamentally associated with the lifetime ($\tau$) of these charges, which undergo a recombination process. This $\tau$ is a superposition of radiative and non-radiative recombination components, and can be determined by finding the small perturbation in $E_{fn} - E_{fp}$ after the light is switched off (transient state). Hence, $\tau$ can be estimated using $V_{OC}$ decay and the following relation [3,4].

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**Fig. 5.** Prolonged $V_{OC}$ of the glass/ITO/ZnO/NiO/Ag microink device. Stability, repeatability and effect of UV intensity (a) 10 mW/cm$^2$ and (b) 20 mW/cm$^2$ were examined.
Fig. 6. Current-voltage characteristics of the Ag microink/NiO/ZnO/ITO/glass device using light wavelengths of (a) $\lambda = 623$ nm (intermediate-band optical excitation) (inset: $V_{OC}$ of 28 mV and zero-bias photocurrent), (b) $\lambda = 520$ nm (intermediate-band optical excitation) (inset: $V_{OC}$ of 80 mV and zero-bias photocurrent), (c) $\lambda = 460$ nm (intermediate-band optical excitation), (d) $\lambda = 410$ nm (bound excitonic optical excitation), (e) $\lambda = 400$ nm (bound excitonic optical excitation), (f) $\lambda = 385$ nm (free-excitonic optical excitation), (g) $\lambda = 365$ nm (band-to-band optical excitation). Steady-state analysis (J-V characteristics) of the ITO/ZnO/NiO/Ag microink device (device area $= 7.065$ mm$^2$).

The condition for ZnO layer deposition is presented as follow.

| Target | ZnO ($\phi 4$ inch, purity 99.999%) |
|--------|----------------------------------|
| RF power | 300 W |
| Gas/Flow rate | Ar, 50 sccm |
| Working pressure | 5 mTorr |
| Temperature | Room temperature |
| Deposition time | 60 minutes |

The condition for NiO layer deposition is presented as follow.

| Target | Ni ($\phi 4$ inch, purity 99.999%) |
|--------|----------------------------------|
| DC power | 50 W |
| Gas/Flow rate | Ar/O$_2$, 30/4 sccm |
| Working pressure | 3mTorr |
| Temperature | Room temperature |
| Deposition time | 60 minutes |
\[ \tau = -\frac{kT}{q} \left( \frac{dV_{OC}}{dt} \right)^{-1} \]  

(2)

where \( k \) is the Boltzmann constant \((1.38 \times 10^{-23} \text{ J K}^{-1})\), and \( T \) is the absolute temperature. Moreover, \( V_{OC} \) as a function of \( E_g \) and charge-carrier density (electrons \((n)\) and, holes \((p)\)) can be written as the following.

\[ qV_{OC} = E_g - \ln(NcNv/np) \]  

(3)

where \( Nc \) and \( Nv \) are the effective densities of states of electrons and holes, respectively, which are constants. According to this relation, \( V_{OC} \) in the device depends on the number densities of photogenerated \( n \) and \( p \) and can reach as high as the value of \( E_g \) Refs. [3,4].

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dib.2019.104095.

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