Data Article

Physical and chemical data of WS$_2$ platelets and thickness-dependent photoresponses

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**Abstract**

In this data article, the properties of WS$_2$/ZnO type-I heterostructure which corresponds to the research article "Vertically trigonal WS$_2$ layer embedded heterostructure for enhanced ultraviolet-visible photodetector" (Nguyen et al., 2018) are presented by characteristics of WS$_2$ layer, diode properties, and thickness dependent photoresponses. The device performances under the effect of rapid thermal processing (RTP) is presented. The WS$_2$ platelets grown by large area sputtering method (Nguyen et al., 2018) was characterized in term of morphology and chemical elements distribution by using transmission electron microscope (TEM), energy dispersive spectroscopy (EDS) and X-Ray photoelectron spectroscopy (XPS). Diode characterization of WS$_2$/ZnO like rectifying ratio, ideal factor and barrier height are presented. The variation of photocurrent of ITO/WS$_2$/ZnO/FTO/glass photodetector, its dependence on the WS$_2$ thickness and influence of post- thermal treatment are presented.

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### Specifications Table

| Subject area                        | Physics, Electrical Engineering |
|-------------------------------------|----------------------------------|
| More specific subject area          | Photodetector                    |
| Type of data                        | Figures, Table                   |
| How data was acquired               | Transmission electron microscope  |
|                                     | (TEM, TALOS F200X)               |
|                                     | Energy dispersive spectroscopy    |
|                                     | (EDS, JEOL, JSM_7001F)           |
|                                     | X-ray photoelectron spectroscopy  |
|                                     | (XPS, PHI 5000 VersaProbe-II, ULVAC) |
|                                     | Potentiostat/galvanostat (PGStat, ZIVE SP1, WonA Tech) |
|                                     | Function generator (MFG-3013A, MCH Instruments) |
| Data format                         | Analyzed                         |
| Experimental factors                | Current-Voltage (I-V) characteristics: Linear sweep voltammetry, scan range: $-0.6$ to $0.6$ V, positive direction, scan rate $100$ mV/s |
|                                     | Mott-Schottky: Potentialdynamic impedance spectroscopy, scan range: $-1$ V to $0.2$ V, step size: $25$ mV, A/C signal amplitude: $10$ mV, frequency range: $1$ MHz–$100$ Hz, normal speed. |
|                                     | Transient photosresponse: Chronoamperometry, light source: ultraviolet ($\lambda = 365$ nm), applied voltage: $-1$V, pulsed light frequency: $10$ Hz, light intensity: $6$ mW cm$^{-2}$. |
| Experimental features               | WS$_2$/ZnO heterostructure properties, effect of heat treatment and WS$_2$ thickness on the photocurrent of device |
| Data source location                | Incheon National University, Incheon-406772, South Korea |
| Data accessibility                  | The data are available with this article |
| Related research article            | T.T. Nguyen, M. Patel, D.K. Ban, J. Kim. Vertically trigonal WS$_2$ layer embedded heterostructure for enhanced ultraviolet–visible photodetector. J. Alloys Compd. 768, 2018, 143–149 [1]. |

### Value of the Data

- The data relates to chemical states of WS$_2$ platelet could be useful to study the defect engineering of WS$_2$ material
- WS$_2$/ZnO type-I heterostructure design is efficient for the large scale transitional metal dichalcogenides (TMDs) for optoelectronics.
- Effect of the thickness of WS$_2$ layer was investigated for the photocurrent profiles.

1. **Data**

The quantities of various oxidation states of tungsten are presented in Fig. 1 by using XPS measurement. Further, Fig. 2 shows the morphology of vertical WS$_2$ platelets grown by sputtering method [1] and the distribution of W and S in the WS$_2$. The diode properties of WS$_2$/ZnO structure includes the rectifying ratio, diode ideality factor and potential barrier height are presented in Fig. 3. In addition, the transient photocurrent profiles of WS$_2$/ZnO device are presented in Fig. 4 (at $\pm 1$ bias). The parameters used to simulate the band diagram of the WS$_2$/ZnO heterostructure are summarized in the Table 1 for Solar Sell Capacitance Simulator (SCAPS) [1]. Later, considering properties of vertically grown WS$_2$ as well as WS$_2$/ZnO heterostructure, the effect of post-treatment by RTP treatment and WS$_2$ deposition time on ITO/WS$_2$/ZnO/FTO device performance is shown in Figs. 5 and 6, respectively.
Fig. 1. (a) The XPS spectra of tungsten in WS$_2$ sample with the inset of image of ITO/WS$_2$/ZnO/FTO device. (b) Summary of the quantity of each oxidation state of tungsten in WS$_2$ sample.

| Component    | Area under each XPS peak | Percentage of each component (%) |
|--------------|---------------------------|----------------------------------|
| W 4f 7/2     | 20782.67                  | 42.45                            |
| W 4f 5/2     | 21757.61                  | 44.44                            |
| W 6+         | 4619.83                   | 9.44                             |
| W 5p 3/2     | 1797.13                   | 3.67                             |

Fig. 2. Transmission electron microscope analysis of WS$_2$ platelets. (a) Low resolution TEM image and (b) elemental mapping of WS$_2$ platelets, (c) energy dispersive spectra of WS$_2$ platelets presents the elemental W and S.
2. Experimental design, materials, and methods

2.1. Sample preparation

The FTO glass was used as the substrate for the ITO/WS2/ZnO/FTO fabrication and was cleaned prior to the fabrication process described in Ref. [1]. The ZnO layer was fabricated according to conditions presented in Ref. [2].

![Graph](image)

**Fig. 3.** (a) Semi-log current-voltage (I-V) plot and (b) Mott-Schottky characteristic of WS2/ZnO heterostructure photodiode. Here n and $V_{FB}$ are the diode ideality factor and flat band potential, respectively.

![Graph](image)

**Fig. 4.** Current – time profile of WS2/ZnO photodetector obtained at bias of (a) $-1 \text{ V}$ and (b) $+1 \text{ V}$.

| Table 1 | Parameters in SCAPS simulation. |  |
|---------|---------------------------------|---|
| Material | Thickness (nm) | Bandgap (eV) | Doping concentration (cm$^{-3}$) | Material type | Electron affinity (eV) |
| ZnO     | 100               | 3.3         | $1 \times 10^{16}$             | n type       | 3.87          |
| WS2     | 200               | 1.3         | $6 \times 10^{21}$            | n type       | 4.3           |

2. Experimental design, materials, and methods

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Fig. 5. Current-time profiles of WS₂/ZnO heterostructure obtained under same operation conditions. (a) Pristine, (b) RTP treated at 300 °C and (c) RTP treated at 350 °C. (RTP condition: flowing Argon at 0.5 lpm, pressure of 20 mTorr, holding time of 5 min).
The condition for WS₂ layer deposition is presented as follow

| Target          | WS₂ (⌀2 in., purity 99.999%) |
|-----------------|-------------------------------|
| RF power        | 50 W                          |
| Gas/Flow rate   | Ar, 20 sccm                   |
| Working pressure| 4 mTorr                       |
| Temperature     | 400 °C                        |
| Deposition time | 10 min, 20 min, 30 min        |

The condition for ITO layer deposition is presented as follow

| Target          | ITO (⌀4 in., purity 99.999%) |
|-----------------|-------------------------------|
| RF power        | 300 W                         |
| Gas/Flow rate   | Ar 50 sccm/O₂ 0.3 sccm        |
| Working pressure| 5 mTorr                       |
| Temperature     | Ambient temperature           |
| Deposition time | 10 min                        |

2.2. Sample characterization

The quantities of various tungsten oxidation states are described in Fig. 1 by performing chemical analysis of the WS₂ platelets on the Si substrate using X-ray photoelectron spectroscopy (XPS, PHI 5000 VersaProbe-II, ULVAC). Property of vertical WS₂ layer was examining by transmission electron microscope (TEM, TALOS F200X) as presented by Fig. 2a. The chemical elemental mapping of WS₂ platelets are presented by Fig. 2b with the detail distribution of W and S elements characterized by Fig. 2c using energy dispersive spectroscopy (EDS, JEOL, JSM_7001F). The diode properties of WS₂/ZnO structure (rectifying ratio, ideal factor and barrier height) are presented by Fig. 3. The current-voltage property of WS₂/ZnO device as presented by Fig. 3a was analyzed by using potentionstat/galvanostat (PGStat, ZIVE SP1, WonA Tech) using linear sweep voltammetry. The barrier height of 0.06 V of WS₂/ZnO heterostructure is obtained by analyzing the flat-band potential of WS₂/ZnO heterostructure which determined from the Mott-Schottky characteristics as presented by Fig. 3b. Fig. 4 presents the current-time property of the device at bias of ± 1. The illustration of band diagram

![Graph showing photocurrent vs WS₂ deposition time](image-url)

**Fig. 6.** The photocurrent vs WS₂ deposition time of the ITO/WS₂/ZnO/FTO device under UV illumination.
of WS$_2$/ZnO heterostructure which characterized by one-dimensional drift–diffusion equation solver program (SCAPS) [1] is based on material parameters presented by Table 1. The effects of RTP treatment and WS$_2$ deposition time on ITO/WS$_2$/ZnO/FTO device performances were studied by analyzing current–time characteristics of the device using chronoamperometry. The frequency and power of the light source were modulated by using a function generator (MFG-3013A, MCH instruments). Fig. 5 presents the photocurrent of the device under different temperature conditions of RTP process. And the correlation between photocurrent of the device and WS$_2$ time deposition is presented by Fig. 6.

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**Transparency document. Supporting information**

Transparency data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2018.08.118.

**References**

[1] T.T. Nguyen, M. Patel, D.K. Ban, J. Kim, Vertically trigonal WS$_2$ layer embedded heterostructure for enhanced ultraviolet–visible photodetector, *J. Alloy. Compd.* 768 (2018) 143–149.

[2] M. Patel, J. Kim, Integrated spectral photocurrent density and reproducibility analyses of excitonic ZnO/NiO heterojunction, *Data Brief* 15 (2017) 81–85.