**Supplemental Materials**

**Investigating** **the preparation process of excellent Cu3VSe4 absorption layer prepared by** **amine-thiol system**

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Figure S1. XRD pattern of as-deposited Cu3VSe4 thin films.

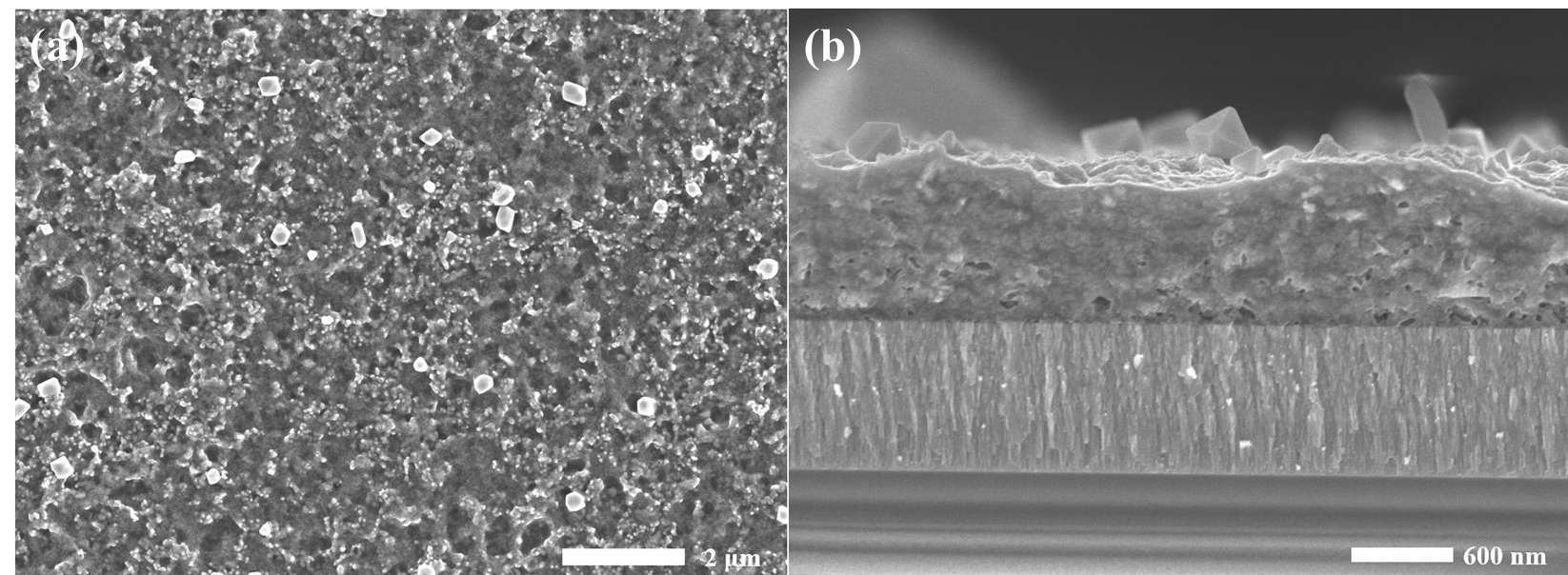


Figure S2. (a) Surface and (b) cross-sectional images of as-deposited Cu3VSe4 thin films.

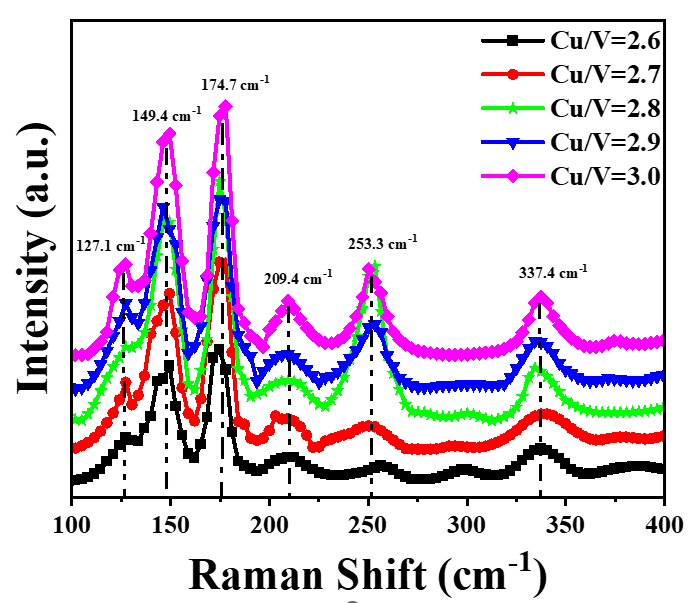
Figure S3. Raman spectra of the selenized Cu3VSe4 films with the various Cu/V ratios.



Figure S4. Top view and cross-sectional SEM images of the selenized Cu3VSe4 films with the various Cu/V ratios. (a, a-1) 2.7, (b, b-1) 2.75, (c, c-1) 2.8, (d, d-1) 2.85.

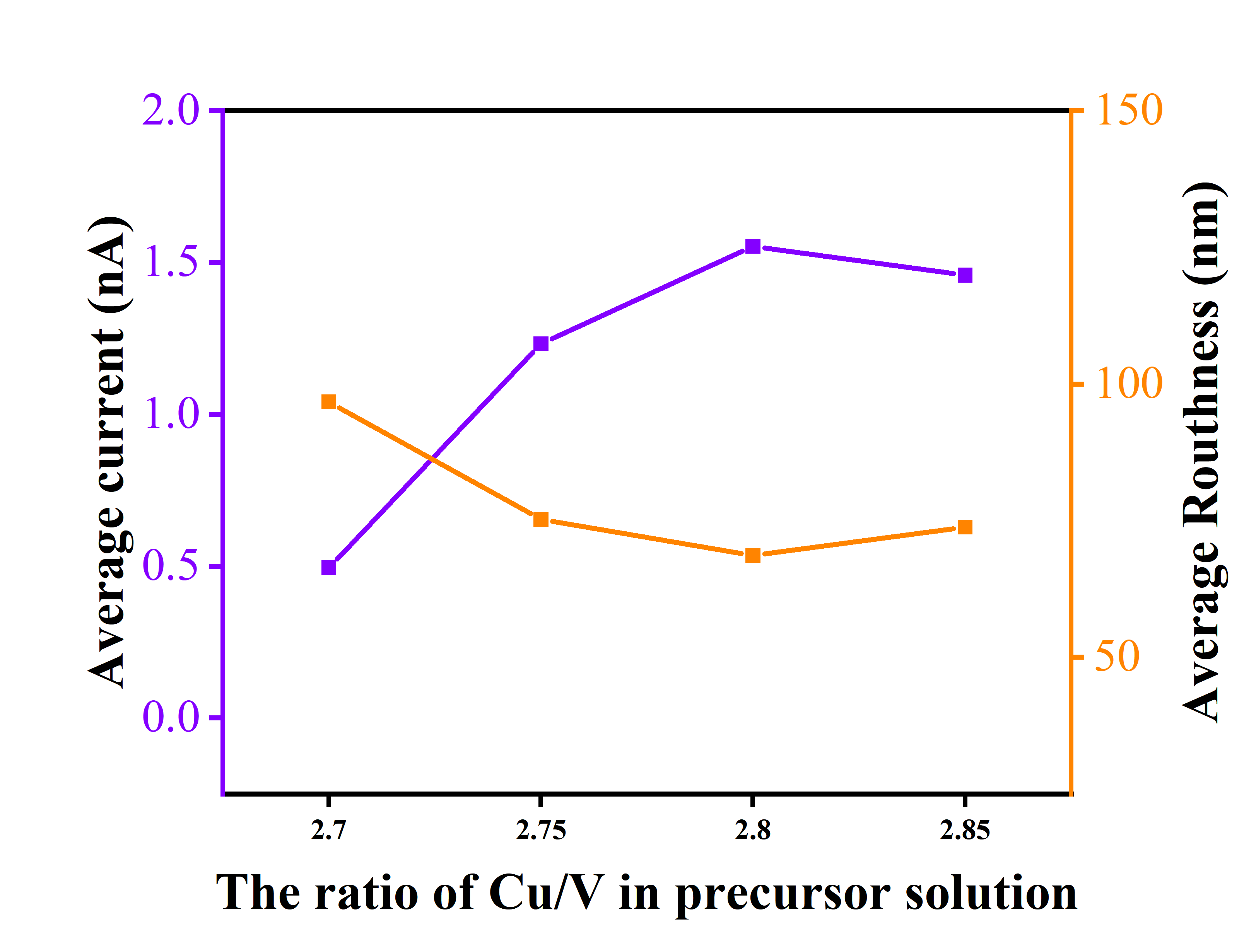


Figure S5. The average surface current and roughness of the selenized Cu3VSe4 films with the various Cu/V ratios.

Table S1 Half-high width of Cu2.8VSe4 films with the different temperatures of HT process.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| two-step selenization process | 400-10-550-30 | 400-10-560-30 | 400-10-570-30 | 400-10-580-30 |
| half-high width | 0.15214 | 0.17599 | 0.11813 | 0.13112 |

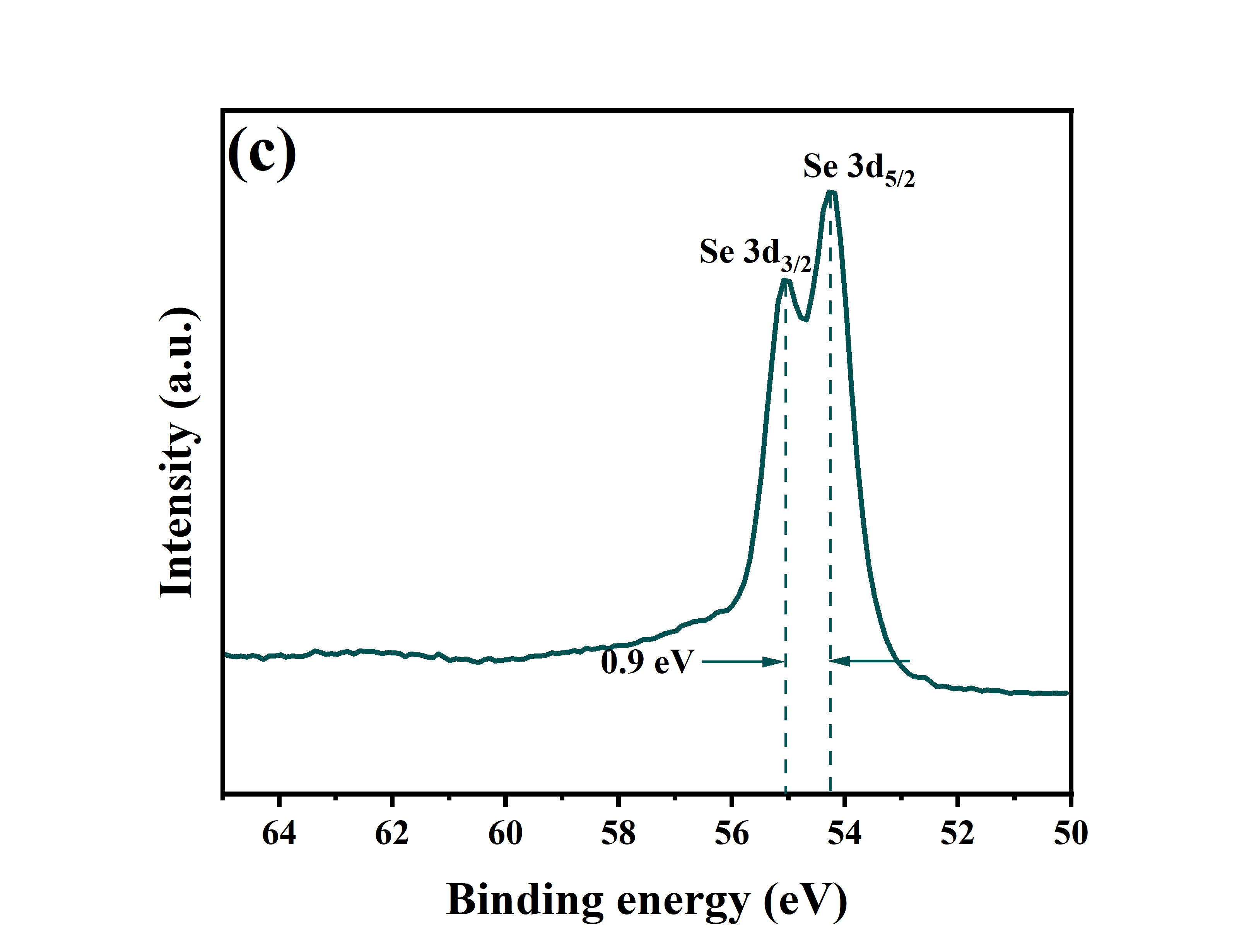
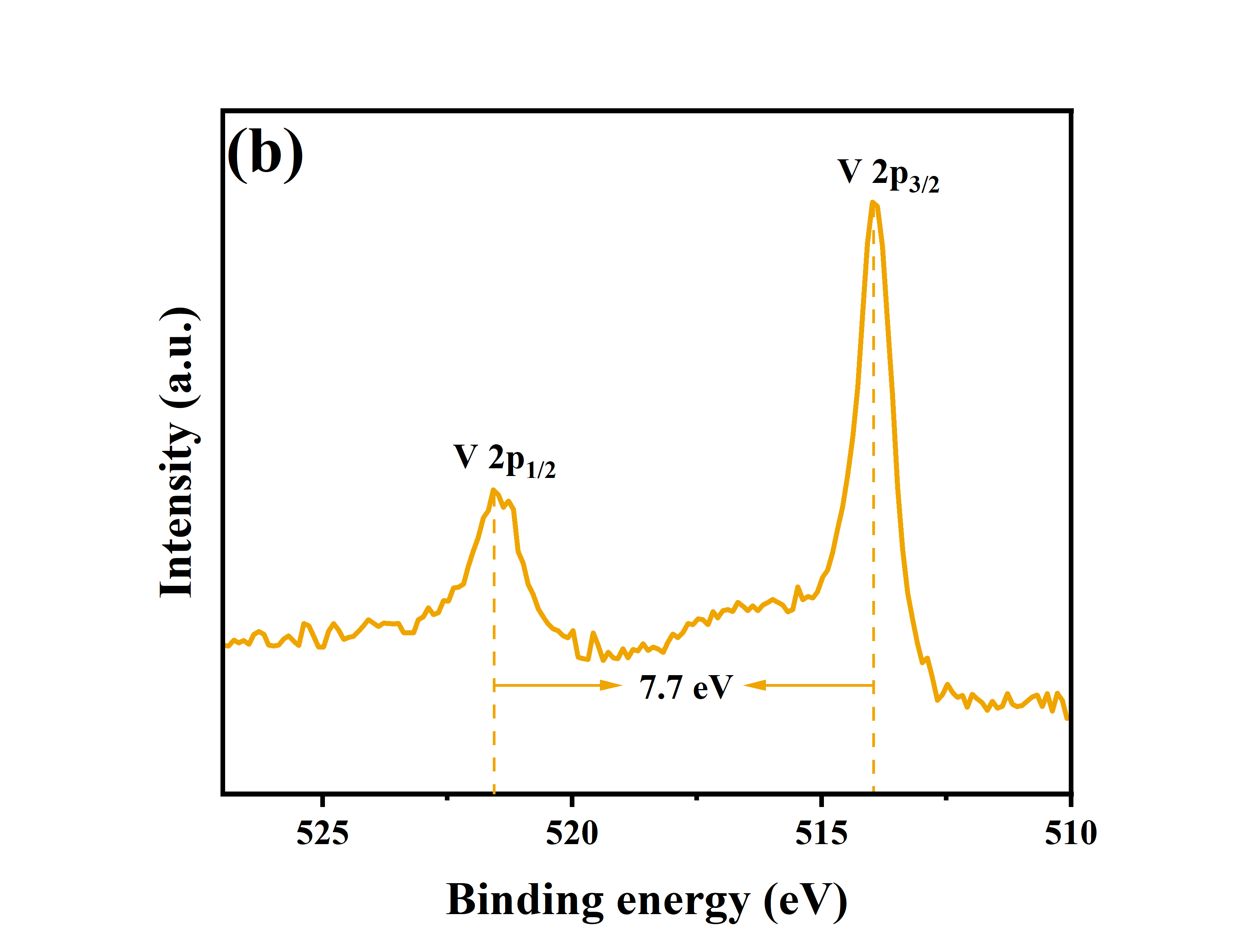
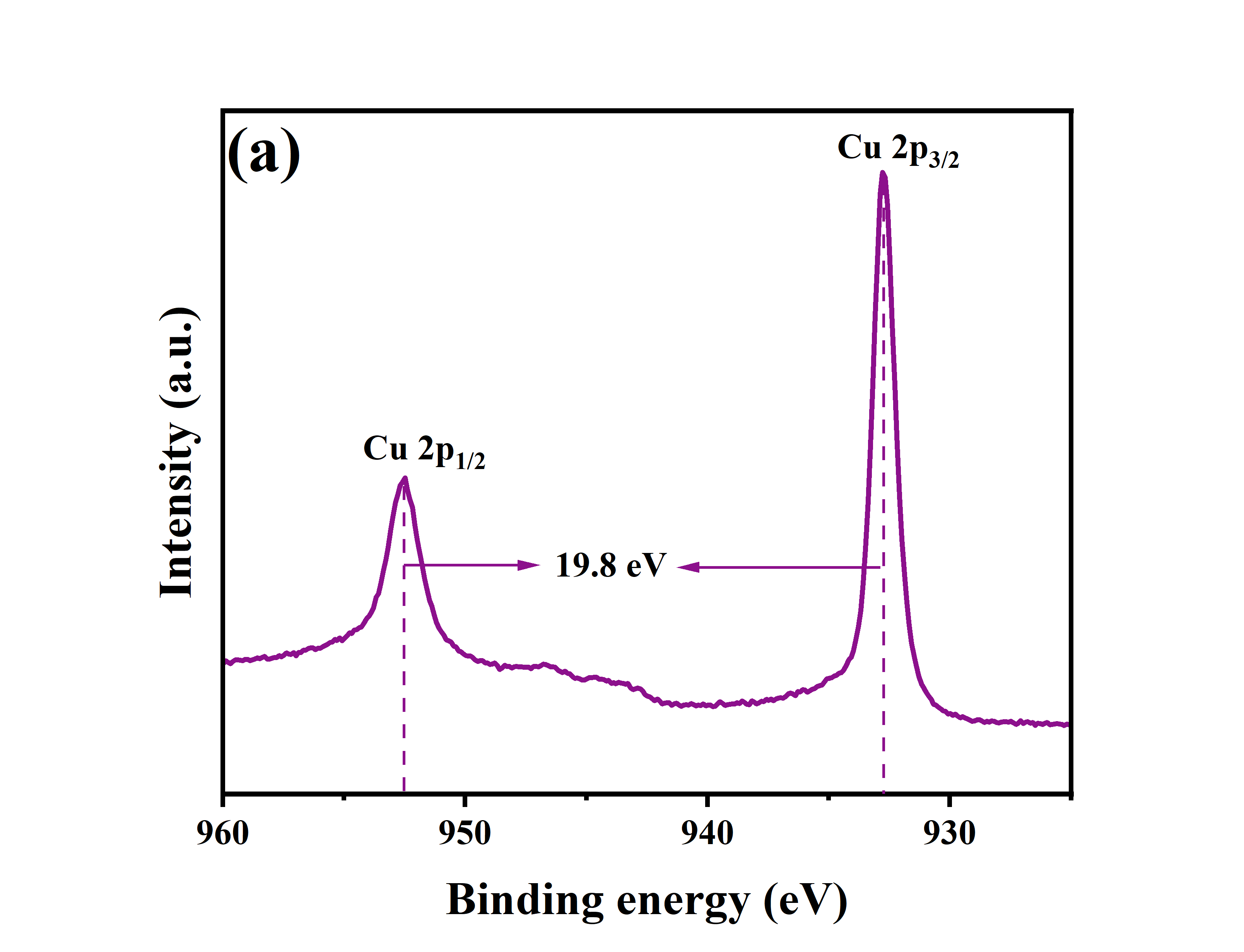


Figure S6. XPS spectra of the best sample. (a) Cu, (b) V, (c) Se.