Study on the effect of different oxygen flow rates on vanadium-doped zinc oxide thin film piezoelectric pressure sensors.

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The piezoelectric effect is a phenomenon where certain materials generate an electric charge when subjected to mechanical stress. This property is widely utilized in sensors, actuators, and energy-harvesting devices because it converts mechanical energy into electrical energy. Zinc oxide (ZnO) is a promising material for energy-harvesting devices due to its piezoelectric and semiconductor properties, along with good biocompatibility and low environmental impact. However, its relatively low piezoelectric coefficient (12.4 pC/N) limits its potential in these applications.To enhance the piezoelectric coefficient, vanadium (V) was doped into ZnO thin films. Vanadium ions (V^{5+}/V^{3+}) have a higher valence than zinc ions (Zn^{2+}), which improves electric polarization and increases the piezoelectric coefficient. Additionally, V^{5+} ions, having a higher positive charge than V^{3+} ions, create stronger polarity, further boosting the piezoelectric properties. By adjusting the oxygen flow rate during the sputtering process, the V^{5+} content in the films is increased, enhancing the piezoelectric coefficient.

In this study, we utilized an RF sputtering system with varying oxygen flow rates to prepare vanadium-doped zinc oxide (V-ZnO) thin films, which were then used to fabricate piezoelectric pressure sensor devices. The results show that as the oxygen flow rate increases, the grain shape of the thin films changes, and the grain size decreases. SEM images reveal significant changes in the grain structure. XRD analysis shows that the intensity of the 002 peak weakens as the oxygen flow rate increases, indicating structural changes in the thin films. XPS analysis reveals that the content of pentavalent vanadium increases with higher oxygen flow rates, but decreases after reaching a critical value, which correlates with the trend observed in piezoelectric coefficient measurements. Further analysis of the O1s XPS spectra shows that the lattice oxygen content in the films is higher than the surface adsorbed oxygen, with the lowest number of oxygen vacancies at a certain oxygen flow rate, which then increases as the oxygen flow rate rises. UV-visible spectra indicate that, due to the Burstein-Moss effect, the energy band structure of the thin films initially decreases and then increases with increasing oxygen flow rates.Finally, piezoelectric pressure sensors were fabricated from these thin films, and the pressure sensitivity at different oxygen flow rates was measured. This study provides a comprehensive investigation of the structural, optical, and piezoelectric properties of vanadium-doped zinc oxide thin films at varying oxygen flow rates and explores their application as piezoelectric pressure sensors. The findings offer valuable insights for optimizing thin film performance in piezoelectric sensing devices.

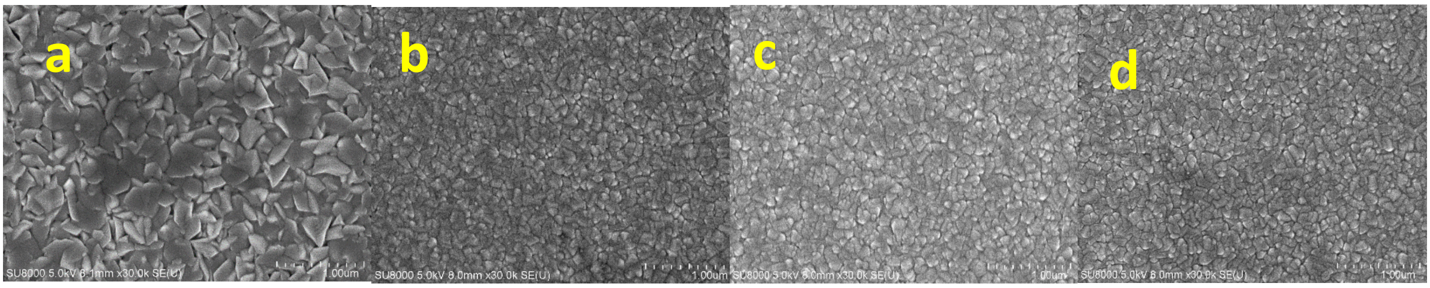

Fig.1 Plan-view images of V doped ZnO with different oxygen flow rate.(a)0sccm(b)10sccm(c)20sccm(d)30sccm

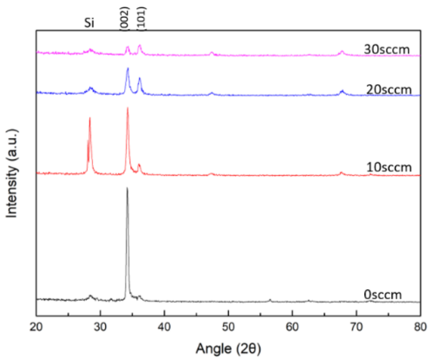

Fig.2. XRD patterns of V doped ZnO with different oxygen flow rate

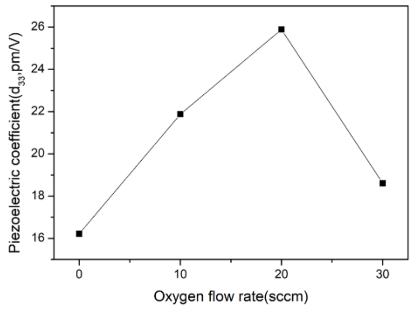

Fig.3 The d_{33} of V doped ZnO with different oxygen flow rate

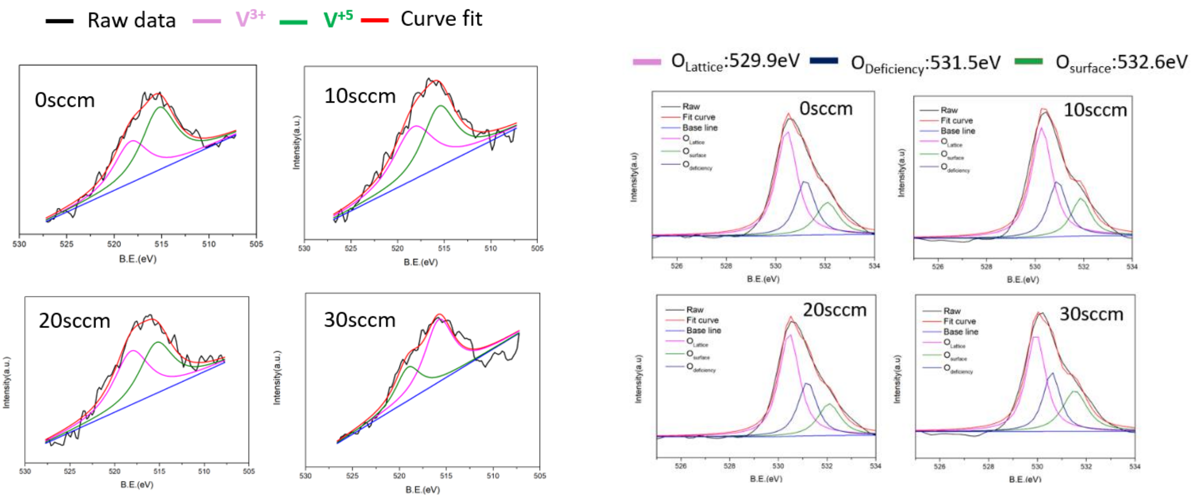

Fig.4 XPS spectra for V doped ZnO with different oxygen flow rate

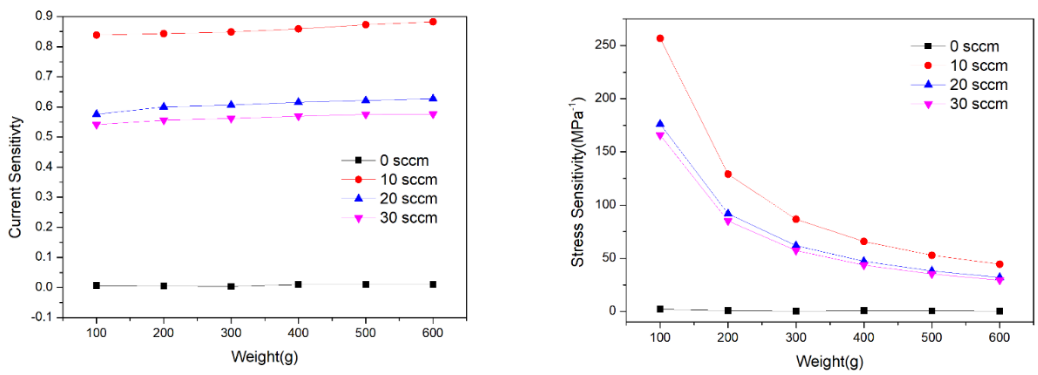

Fig.5 Sensor performance of V doped ZnO with different oxygen flow rate (a)current sensitivity (b)stress sensitiviy