Influence of Preparation Ambient on Luminescent and Electrical Properties of TiO_2:Sm Thin Films

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Rare earth (RE) doped TiO_2 (TiO_2:RE) shows sharp and strong emission, which makes it a promising candidate for applications in optoelectronic devices. Generally, oxygen-deficient oxide semiconductors such as TiO_2 behave as n-type, which generate free electrons. [1] It suggests that an increase in oxygen vacancies could enhance carrier concentration and reduce resistivity. On the other hand, oxygen also plays an important role in the luminescent properties of RE-doped oxide semiconductors. A 6-fold oxygen surrounds the RE ions critically influencing their luminescent properties. For instance, Samarium (Sm)-doped TiO_2 showed a significant improvement in its luminescent intensity, when the local fine structure around Sm^{3+} was distorted. [2] Therefore, this study reveals how the fabrication and annealing atmospheres (N_2+H_2 and O_2) influence the coordination and structure around Sm^{3+} and their effect on the luminescent properties of TiO_2:Sm thin films. Furthermore, the electrical properties including carrier concentration determined by capacitance-voltage (CV) measurements are discussed.

TiO_2:Sm thin films were deposited on $SrTiO_3$:Nb (100) substrates using pulsed laser deposition (PLD). A ceramic target consisting of TiO_2 and Sm_2O_3 (1 wt%) was laser ablated by the third harmonic generation (355 nm) of a Q-switched yttrium aluminum garnet (YAG) laser. A chamber was controlled under the pressure of 1.0×10^{-2} Torr in atmospheres of O_2 and H_2+N_2 forming gas (H_2:N_2=5:95%). The films were annealed at 700°C for 10 minutes in either an O_2 atmosphere or a H_2+N_2 forming gas atmosphere. RuO_2 was deposited on the TiO_2:Sm thin films to make Schottky contacts for CV and current-voltage (IV) measurements.

Figure 1 shows photoluminescence (PL) spectra of TiO_2:Sm thin films with different fabricating and annealing atmospheres. Samples prepared in an O_2 atmosphere for both the deposition and annealing phases (denoted as OO) exhibited the strongest PL intensity. In contrast, samples deposited in a H_2 atmosphere and annealed in an O_2 (HO), as well as those deposited in an O_2 and annealed in a H_2 (OH), exhibited significantly weaker than OO PL intensity. The luminescence intensity of HO was about one-eighth and OH about one-fifteenth of that observed for OO. Samples processed in a H_2 atmosphere for both deposition and annealing (HH) did not exhibit any luminescence. However, IV and CV measurements revealed that the HH sample marked the highest conductivity with carrier concentrations exceeding $10^{19}/cm^3$. This is markedly higher than that for OO, OH, and HO, hovering around $10^{17}/cm^3$. Further details including the local fine structure around Sm^{3+} in TiO_2 matrix characterized by X-ray absorption fine structure (XAFS) analysis, evaluations of crystallinity via X-ray diffraction (XRD), and detailed outcomes of both CV and I-V measurements and its effect on luminescent and electrical properties will be discussed.

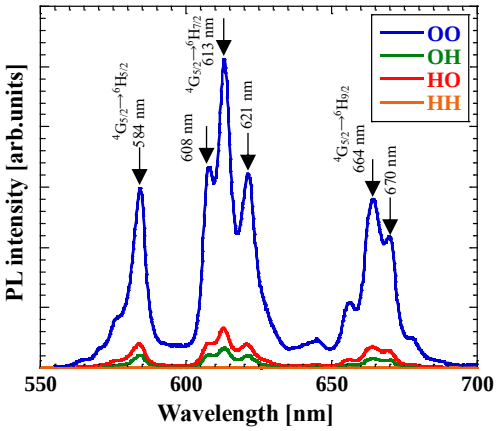

Fig.1. PL spectra of TiO_2:Sm with different fabricating/annealing atmospheres.

References

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