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Synthesis and characterization of niobium pentoxide material modified by plasmonic nano metal using pulsed laser deposition technique

A Thesis

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ABSTRACT

In this work, niobium pentoxide (Nb_2O_5) thin films were successfully synthesized by Q-switched Nd:YAG pulsed laser deposition (PLD) technique and enhanced with plasmonic metal nanoparticles. The structural properties of the prepared Nb_2O_5 thin films showed a phase transformation of Nb_2O_5 from amorphous into polycrystalline structures assigned as orthorhombic (T-Nb_2O_5) and monoclinic (H-Nb_2O_5). A significant reduction of the films' band gaps from 4.91 to 3.29 eV was obtained as the laser fluence increased to 21 $J.cm^{-2}$. Raman scattering revealed well-agreement with the XRD structures for the two prepared structural phases. The substrate temperature showed an enhancement in the crystallization of the prepared material with optimum results at 450 °C. At this temperature, the average particle size was slightly exceeding 60 nm as reported by AFM results with a further reduction in the estimated optical band gap reaching to about 2.90 eV. The impact of the number of laser pulses showed that the optimum film's thickness could be achieved by using 400 laser pulses, where the optical band gap was about 3.37 eV with an average particle size of 66.4 nm. It also provided the best figure of merit (F.O.M.) with an electrical conductivity of 7.33 $\mu S.cm^{-1}$. By using the second harmonic generation wavelength (532 nm), Nb_2O_5 thin film showed a smaller particle size than 44 nm, while the estimated band gap was 3.12 eV. The multi-optimized Nb_2O_5 thin films were decorated with the plasmonic effect of silver (Ag) nanoparticles by immersing the prepared thin films in $AgNO_3$ aqueous with different times. Reduction of silver (Ag) atoms were performed via the photo-activation process. The optimum properties of Ag@Nb_2O_5 were obtained at 25 sec, that the optical band gap reduced from 3.37 eV to 3.28 eV with an electrical conductivity of 10.85 $\mu S.cm^{-1}$. This work also includes the preparation and characterization of Ag@Nb_2O_5/Si heterojunction device. Investigating the performance of the device quality insured a good rectification with a spectral responsivity at 420 nm as compared to 370 nm for the referenced Nb_2O_5/Si. The detectivity was $1.69*10^{12}$ J for Ag@Nb_2O_5/Si in comparison with $1.28*10^{12}$ Jones for Nb_2O_5/Si. The external quantum efficiency (E.Q.E.) showed an enhancement by 9.4% for Ag@Nb_2O_5/Si as compared with Nb_2O_5/Si.