Materials Science and Engineering B 288 (2023) 116212

Contents lists available at ScienceDirect

Materials Science & Engineering B

journal homepage: www.elsevier.com/locate/mseb

Ion beam irradiation: Novel approach for preparation of Ag coated N doped nanocrystalline anatase TiO_2 films

P.N. Wani [a], S.K. Kale [b], S.S. Dahiwale [c], Umesh T. Nakate [d,*], S.U. Ekar [e], Yogesh T. Nakate [f], P.S. More [g], M.T. Sarode [h], Y.B. Khollam [e,*]

[a] Department of Physics, Prof. Ramkrishna More ACS College, Akurdi, Pune 411 044, Maharashtra, India
[b] Department of Applied Science, Pimpri Chinchwad College of Engineering, Nigadi, Pune 411 044, Maharashtra, India
[c] Department of Physics, Savitribai Phule Pune University, Ganeshkhind, Pune 411 007, India
[d] Department of Polymer-Nano Science and Technology, Jeonbuk National University (JBNU), Jeonju-Si, Jeollabuk-do, Republic of Korea
[e] Department of Physics, Baburaoji Gholap College, Sangvi, Pune 411 027, Maharashtra, India
[f] Department of Electronics, K.B.C.N.M University, Jalgaon 425 001, Maharashtra, India
[g] Nanomaterials Application Laboratory, The Institute of Science, Dr. Homi Bhabha State University, Mumbai 400 032, Maharashtra, India
[h] Department of Physics, Mahatma Phule Mahavidyalaya, Pimpri, Pune 411 017, Maharashtra, India

ARTICLE INFO

Keywords:
Anatase TiO_2
N/Ag doped TiO_2
Nitrogen irradiation, Electrochemical Impedance Spectroscopy (EIS)
Raman spectroscopy

ABSTRACT

Herein, a novel approach of ion beam irradiation (nitrogen beam dose – 10^{13} ions/cm^2, 40 keV for 30 min in ultra-high vacuum conditions) is explored for the preparation of nanocrystalline anatase TiO_2 modified with nitrogen (N) and silver (Ag). The prepared materials characterized using XRD, Raman, UV–Visible spectroscopy, EIS and wettability techniques. The structural-optical studies revealed the interstitial and/or substitutional doping of N in O-Ti-O matrix supported by Williamson-Hall lattice strain values and dispersion of Ag^o particles at the TiO_2 surface. Raman spectra confirmed the crystallization of anatase TiO_2 wherein red shifting-broadening of Raman active modes are due to the phonon confinement and structural defects due to favored substitutional N^{3-} doping in TiO_2 lattice. The higher values of Z′, Z″, and R_{CT} in Nyquist plots and the blue shift of ω_{max} in Bode plots for irradiated films further supported the substitutional doping of N rather than the interstitial one.

1. Introduction

In the era of modern advanced technology, the step towards the fabrication of new functional devices is one of the most important revolutions. The metal, as well as semiconductor oxides having remarkable properties, play a leading role in this process of device fabrication [1,2]. Among these oxides, because of the high chemical stability, low cost, better biocompatibility, long-term photo-stability, strong oxidized stability, high thermal stability, and non-toxicity properties, titanium dioxide (TiO_2) is noted to be an important semiconductor oxide. Due to this, a significant amount of research on TiO_2 has been carried out over the last few decades for its potential applications ranging from energy to environmental aspects [3–5]. The semiconducting TiO_2 is proved to be a very useful oxide in many fields like antibacterial applications [6,7], sensors [8,9], photocatalysis for environmental purification, and production of hydrogen from water [10–13], removal of unwanted impurities from water and air [14,15], solar cells [16,17], ceramic membrane and also as a catalyst for photocatalytic decomposition [18–21].

Different nanostructures like nanofibres [19,21] nanowires [22–24], nanotubes [25,26], nanorods [27,28], nanospheres [29], nanoplumes [30] are synthesized for improving the properties of the TiO_2. Doping with metal or nonmetal in TiO_2 may be an effective solution to expand its properties in various fields. The addition of ion impurity incorporated in TiO_2 is more beneficial to amend physicochemical properties such as optoelectronic property, photocatalytic property, photovoltaic property, *etc.* [31–33]. Either metal (transition metals: Cu, Co, Ni, Cr, Mn, Mo, Nb, V, Fe, Ru, noble metals: Pt, Ag, Au) or nonmetal (*e.g.* B, S, P, C, N, F, I) ion implantation in TiO_2 is a good practice for the researcher to tune its optical, electrical, photocatalytic and magnetic properties [31]. Lots of procedures such as ion-assisted sputtering, chemical vapor deposition, sol–gel, chemical mixing, magnetron sputtering, and ion implantation [31,34–38] were adapted by researchers for doping the TiO_2.

TiO_2 is a promising photocatalyst in the ultraviolet region. The nitrogen-doped TiO_2 lowers the bandgap of TiO_2, showing good

* Corresponding authors.
E-mail addresses: umesh.nakate@jbnu.ac.kr, umesh.nakate@gmail.com (U.T. Nakate), ykhollam@yahoo.co.in (Y.B. Khollam).

https://doi.org/10.1016/j.mseb.2022.116212
Received 8 May 2022; Received in revised form 23 November 2022; Accepted 27 November 2022
Available online 16 December 2022
0921-5107/