Journal of Alloys and Compounds 882 (2021) 160671

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

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

Effects of MWCNTs/graphene nanoflakes/MXene addition to TiO_2 thick film on hydrogen gas sensing

Siti Amaniah Mohd Chachuli[a,*], Mohd Nizar Hamidon[b], Mehmet Ertugrul[c], Md Shuhazlly Mamat[d], Omer Coban[e], Fatma Nur Tuzluca[f], Yasar Ozkan Yesilbag[f], N.H. Shamsudin[g,h]

[a] Fakulti Kejuruteraan Elektronik & Kejuruteraan Komputer, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[b] Institute of Advanced Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[c] Engineering Faculty, Ataturk University, 25250 Erzurum, Turkey
[d] Faculty of Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[e] Department of Electrical and Energy, Ispir Hamza Polat Vocational School of Higher Education, Ataturk University, 25250 Erzurum, Turkey
[f] Department of Physics, Erzincan Binali Yıldırım University, 24100 Erzincan, Turkey
[g] Fakulti Kejuruteraan Elektrik, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[h] Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

A R T I C L E I N F O

Article history:
Received 14 March 2021
Received in revised form 28 May 2021
Accepted 31 May 2021
Available online 4 June 2021

Keywords:
MWCNTs
graphene nanoflakes
$Ti_3C_2T_x$ MXene
TiO_2 hydrogen gas sensor
Screen-printing
Thick film

A B S T R A C T

Various doping materials, such as MWCNTs, graphene nanoflakes and MXene, have been doped into TiO_2 and the hydrogen sensing properties investigated. Using a similar volume, MWCNTs (5 wt.%) and graphene nanoflakes (5 wt.%) and MXene (10 wt.%) were added to TiO_2 and prepared in a paste form by mixing the sensing material with the organic binder. The sensing film was deposited on an alumina substrate using a screen-printing technique and annealed at 500 °C for 30 min in ambient air. The crystallinity of TiO_2 and the doped material in the sensing film after the annealing treatment were verified using FESEM, EDX, XRD and Raman Spectroscopy. By depositing an interdigitated electrode at the bottom of the sensing film, the thick film gas sensors (TiO_2/MWCNT, TiO_2/Gr, TiO_2/MXene) were exposed to 100–1000 ppm of hydrogen at an operating temperature of 100–250 °C. The responses showed that the addition of MWCNTs and MXene to TiO_2 reduced the operating temperature of the TiO_2 gas sensor from 150 °C to 100 °C, while the addition of graphene nanoflakes did not affect the operating temperature of the TiO_2 gas sensor. The TiO_2/MWCNT gas sensor showed linear sensitivity as hydrogen concentrations increased for operating temperatures of 100–250 °C. The optimal operating temperature for TiO_2/MXene occurred at 100 °C, while the optimal operating temperature for the TiO_2/Gr gas sensor occurred at 200 °C. The highest sensitivity for 100–500 ppm hydrogen was generated by the TiO_2/MXene gas sensor, and for 600–1000 ppm hydrogen was generated by the TiO_2/MWCNT gas sensor at an operating temperature of 250 °C. The TiO_2/MWCNT gas sensor produced the highest sensitivity to hydrogen at the operating temperature of 250 °C with sensitivity values of approximately 6.36, 33.61, 67.64, 102.23 and 159.07 for 100, 300, 500, 700 ppm and 1000 ppm of hydrogen, respectively.

1. Introduction

With the drive toward zero emissions, research on hydrogen generation has received attention from researchers because hydrogen can be used as a source of alternative energy, especially in fuel cells and transportation for space vehicles. Hydrogen gas is also known as non-toxic, tasteless, odorless and colorless. Therefore, hydrogen cannot be detected by human senses. An excessive amount of hydrogen in the air—greater than 4%—can cause explosions. Additionally, a large amount of hydrogen in the air can also affect the

* Corresponding author.
E-mail addresses: sitiamaniah@utem.edu.my (S.A.M. Chachuli), mnh@upm.edu.my (M.N. Hamidon), ertugurl@atauni.edu.tr (M. Ertugrul), shuhazlly@upm.edu.my (M.S. Mamat), omercoban@atauni.edu.tr (O. Coban), ftuzluca@erzincan.edu.tr (F.N. Tuzluca), oyesilbag@erzincan.edu.tr (Y.O. Yesilbag), nurhazahsha@utem.edu.my (N.H. Shamsudin).

https://doi.org/10.1016/j.jallcom.2021.160671
0925-8388/