Chemistry Africa
https://doi.org/10.1007/s42250-023-00845-7

ORIGINAL ARTICLE

Phase Transformation and Photoluminescence Properties of $MgTiO_3$:Mn^{4+} Synthesis by Modified Sol–Gel Method

Bahaa Wathook[1,2] · Dhia A. Hassan[1] · Shiqing Pang[3] · Xu Jian[3]

Received: 1 August 2023 / Accepted: 22 November 2023

Abstract

This present study produced a red-emitting phosphor (REP) made of magnesium titanate ($MgTiO_3$) doped with manganese cations (Mn^{4+}) using the sol–gel method. X-ray diffraction (XRD) and infrared (IR) were used to identify the produced compounds before detailed studies were conducted to examine the effects of calcination temperature, Mn^{4+} concentration, and additional magnesium ions on the crystal structure and photoluminescence (PL) properties of the prepared REP. Upon optimising the REP preparation conditions by cooling the sol solution, the obtained gel was heated at 40 °C to dry it and produce a powder that was then calcined at 600–800 °C. This modification not only decreased the polymerisation and calcination temperature but calcination time as well. Changing the magnesium ratio and calcination temperature significantly altered the phase of the Mn^{4+} in the octahedral structure of the perovskite host. Scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) were used to examine the morphology of the produced REP particles. The produced REP was then combined with a cerium cation (Ce^{3+})-doped yellow yttrium aluminium garnet (YAG) phosphor and a SYLGARD 184 polydimethylsiloxane (PDMS) polymer and coated on a 450 nm-blue indium gallium nitride (InGaN) LED chip to fabricate a white light-emitting diodes (wLED) that produced a natural white color. Therefore, the proposed Mn^{4+}-doped $MgTiO_3$-based REP is a promising material for wLED applications.

Keywords Phosphor · Magnesium titanate · Manganese doping · Photoluminescence · Phase transformation · Sol–gel · LED

1 Introduction

Light-emitting diodes (LEDs) are not only the most environmentally friendly and energy-efficient lighting technology but they are cheap, have a long service life, and are mercury-free, unlike conventional solid-state lighting technologies [1, 2]. At present, white light-emitting diodes (wLEDs) are commonly made using blue indium gallium nitride (InGaN) LED chips and cerium cation (Ce^{3+})-doped yellow yttrium aluminium garnet (YAG) phosphors. However, as this system lacks a red component, it has a low color rendering index (CRI) and high correlated color temperature (CCT), which makes it difficult to apply in indoor lighting applications or as backlights in liquid crystal displays (LCDs) [3–5]. Nevertheless, these limitations can be overcome by incorporating a suitable and effective red-emitting phosphor (REP) in its design [6, 7].

Over the years, multiple studies have examined REPs made of Li_4AlSbO_6 doped with manganese cations (Mn^{4+}) [8], $LiZnNbO_4$ doped with Mn^{4+} [9], $Li_2Ca_2Mg_2SiN_6$ doped

✉ Dhia A. Hassan
dhia.hassan@uobasrah.edu.iq; dhia_hassan@yahoo.com

Bahaa Wathook
bwathook@gmail.com

Shiqing Pang
212111020038@home.hpu.edu.cn

Xu Jian
xujian@hpu.edu.cn

1 Department of Chemistry, College of Education for Pure Sciences, University of Basrah, Basrah 61004, Iraq

2 Educational Directorate of Basrah, Ministry of Education, Basrah 61001, Iraq

3 Lab of New Energy Materials and Devices, School of Physics and Electronic Information, Henan Polytechnic University, Jiaozuo 454000, China

Published online: 23 December 2023