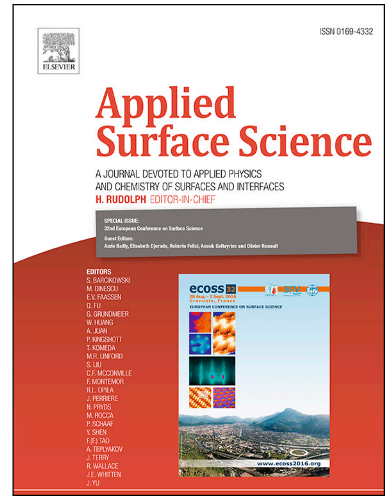

Full Length Article

Formation of size controlled Ge nanocrystals in Er-doped ZnO matrix and their enhancement effect in 1.54 μm photoluminescence

Ranran Fan, Fei Lu, Kaikai Li, Kaijing Liu

PII: S0169-4332(18)30547-6
DOI: https://doi.org/10.1016/j.apsusc.2018.02.192
Reference: APSUSC 38650

To appear in: *Applied Surface Science*

Received Date: 17 December 2017
Revised Date: 11 February 2018
Accepted Date: 19 February 2018

Formation of size controlled Ge nanocrystals in Er-doped ZnO matrix and their enhancement effect in 1.54 μm photoluminescence

Ranran Fan, Fei Lu*, Kaikai Li, and Kaijing Liu

School of Information Science and Engineering, Shandong University, Jinan 250100, China

E-mail: lufei@sdu.edu.cn

Abstract

This paper investigated the controllable growth of Ge nanocrystal (nc-Ge) in (Ge, Er) co-doped ZnO film, and the relationship between the size of nc-Ge and the enhancement of Er^{3+} related 1.54 μm photoluminescence (PL). It was found that nc-Ge with size of ~5 nm was formed by annealing treatment at 600°C. The intensity of 1.54 μm was significantly enhanced due to the existence of nc-Ge and showed an obvious dependence on nanocrystal size. The size of nc-Ge increased with the increase of the annealing temperature, and the nanocrystal with size of ~5 nm made the most obvious contribution to PL enhancement. Prolonging annealing time could improve the crystalline structure of ZnO matrix but had no effect on PL intensity. The experimental results showed that the PL enhancement was mainly achieved by transferring the energy to Er through the resonance absorption of nc-Ge.

Keywords: Rare-earth-doped ZnO, Ge nanocrystal, photoluminescence, energy transfer

1. Introduction

Quantum dots have many novel electrical and optical properties, making it useful to many important fields, such as electronics, optoelectronics, photovoltaics, and biomedicine [1-5]. Significant efforts have been focused on embedding Si and Ge dots or nanocrystals in wide band gap oxide semiconductors to modify and improve their optoelectronics properties [6,7]. The indirect band gap of both Si and Ge leads to a longer lifetime for electron-hole pairs compared to direct bandgap materials, which makes them less efficiency for radiative recombination, but their nano-structures have been investigated to be an effective medium for energy transfer. Several researches have put forward valuable results on Si nanocrystals related with photoluminescence enhancements and attributed the results to the quantum confinement effect of nano-structure [8]. Ge with a larger Bohr radius of about 24 nm as compared to that of Si (about 5 nm) is expected to have a more pronounced quantum confinement effect [9]. Early studies on Ge nanocrystals (nc-Ge) embedded in host oxide thin films have demonstrated significant relationship between the change on the optical properties and the quantum confinement of electron hole pairs in nc-Ge [10,11]. As a wide bandgap semiconductor, ZnO appears to be a good candidate for embedding quantum confined nanostructure. It has various advantageous features like larger exciton binding energy (60 meV) as compared to other wide band gap materials (such as GaN and ZnSe) and exhibits high resistance to photo corrosion [12,13]. Ge-ZnO composition have been studied in application of electrical devices, for example, a low leakage current is demonstrated in Ge-ZnO heterojunction due to the high-energy difference (2.7 eV) between the valance bands of Ge and ZnO. However, there are few studies on the combination of Ge nanostructures and ZnO material [14-16], the understanding of nc-Ge formation mechanism in ZnO host and their physical and optical properties are still preliminary. Er^{3+} luminescence at 1.54 μm, due to the intra-4f transition from the first excited state to the ground state ($^4I_{13/2}$ - $^4I_{15/2}$), has attracted great interest