

PHOTONICS Research

1.54 μm photoluminescence enhancement of Er^{3+} -doped ZnO films containing nc-Ge: joint effect from Er^{3+} local environment changing and energy transfer of nc-Ge

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ZnO films containing Er and Ge nanocrystals (nc-Ge) were synthesized and their photoluminescence (PL) properties were studied. Visible and near-infrared PL intensities are found to be greatly increased in nc-Ge-containing film. Er-related 1.54 μm emission has been investigated under several excitation conditions upon different kinds of Ge, Er codoped ZnO thin films. 1.54 μm PL enhancement accompanied by the appearance of nc-Ge implies a significant correlation between nc-Ge and PL emission of Er^{3+} . The increased intensity of 1.54 μm in Ge:Er:ZnO film is considered to come from the joint effect of the local potential distortion around Er^{3+} and the possible energy transfer from nc-Ge to Er^{3+} . © 2017 Chinese Laser Press

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1. INTRODUCTION

Doping erbium into semiconductors has attracted enormous interest in optical applications as Er-related 1.54 μm emission is within a wavelength range of minimum loss for silica optical fibers [1]. It has been reported that oxygen codoping and the use of wide-bandgap materials as the host material are effective to enhance the Er-related 1.54 μm emission [2,3]. ZnO is considered to be a promising candidate as a host material for Er doping because of being an oxide with a wide bandgap of about 3.37 eV [4,5]. However, the efficiency of 1.54 μm emission in ZnO:Er thin films has not yet been satisfied. It has been confirmed that through the addition of Si nanocrystals (nc-Si) into SiO_2 , strong Er^{3+} photoluminescence (PL) at room temperature could be obtained [6–10]. Ge nanocrystals (nc-Ge) have many properties (wide size-dependent emission tunability, larger Bohr radius, etc.), which is superior to nc-Si [11]. The luminescence efficiency of Er^{3+} may be enhanced by the introduction of nc-Ge through the change of local environment and recombination of photogenerated excitons in nanocrystals and subsequent energy transfer to Er^{3+} .

Energy transfer from nc-Si to RE^{3+} in a silica host has been intensively investigated in recent years. In comparison, few studies have been found on nc-Ge and Er^{3+} in a ZnO host. In this paper, we deposit ZnO film with codoped Ge, Er in

it by magnetron sputtering. Visible and near-infrared (NIR) PL intensities are found to be greatly increased in 600°C annealed Ge:Er:ZnO film compared to the as-deposited sample and the sample without Ge dopants. A 1.54 μm PL enhancement accompanied by the appearance of nc-Ge in an annealed sample implies a significant correlation between nc-Ge and Er^{3+} . The purpose of this work is to analyze how the nc-Ge participates in the PL enhancement. Our observed results suggest that the increased intensity of 1.54 μm in Ge:Er:ZnO film is the result of the joint effect of two factors: local distortion effect and the energy transfer from the nc-Ge participating in the efficient emission.

A ZnO:Er₂O₃ (Er ~ 0.6 at. %) target with small pieces of 5 mm × 5 mm Ge chips was cosputtered by radio frequency magnetron sputtering onto Al₂O₃ substrates. In the current experiment, Ge concentration was fixed to be about 4% in volume fraction. The deposition was carried out in an oxygen and argon mixed gas atmosphere (Ar/O₂ = 2/5), and the chamber pressure was maintained at a constant value of 0.7 Pa. After deposition, the Ge:Er:ZnO film thickness was measured to be about 400 nm. Postannealing of the film was performed for 20 min at temperature of 600°C in N₂ atmosphere. As a comparison, the Ge:Er:ZnO film (Er ~ 0.3 at. %) and the Er:ZnO film (Er ~ 0.6 at. %) were also deposited under the same