

USING THE TAGUCHI METHOD TO PROPOSE A MATHEMATICAL MODEL FOR STUDY THE DEPOSITION OF DOPED ZnO NANOPARTICLES

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Abstract: The nanoscaled semiconductor are used in recent years in manufacturing electronic and optoelectronic devices. One of the most important transparent conducting oxides is ZnO in nanoscale configuration. This oxide has been used as highly transparent conducting layers in place of some expensive films in flat panel displays and photovoltaic devices.

In our work we proposed a mathematical model, based on the Taguchi method, for study the deposition of doped ZnO nanoparticles.

INTRODUCTION

Recent improvements in the control of background conductivity of ZnO and demonstrations of n-type doping have intensified interest in this material for applications in UV light emitters, varistors, transparent high-power electronics, surface acoustic wave devices, piezoelectric transducers, and chemical and gas sensing. ZnO has several potential advantages over GaN for some of these applications, including the commercial availability of bulk single crystals and a larger exciton binding energy (~60 meV compared with ~25 meV for GaN). The latter property should translate to even brighter light emission than obtained with GaN photonics.

To realize any type of device technology, it is important to have control over the concentration of intentionally introduced impurities, called dopants, which are responsible for the electrical properties of ZnO. The dopants determine whether the current (and, ultimately, the information processed by the device) is carried by electrons or holes. In semiconducting oxides, it is generally possible to achieve one or other of these types, but not both.

The dopants are also called shallow level impurities because they introduce energy levels close to one of the allowed energy bands in the material and are easily ionized as a result. There may also be unintentional impurities introduced during the growth of ZnO that have a deleterious effect on the properties of the material.

TECHNIQUES OF DEPOSITION

Using techniques such as pulsed laser deposition (PLD), molecular beam epitaxy (MBE), or even reactive sputtering, ZnO of reasonable quality can be deposited at lower growth temperatures than GaN.

This leads to the possibility of transparent junctions on cheap substrates such as glass, with the potential to realize low-cost UV lasers or light-emitting diodes for high-density data storage systems, solid-state lighting (where white light is obtained from phosphors excited by blue or UV light-emitting diodes), secure communications, and biodetection. ZnO is a direct band gap semiconductor with $E_g = 3.4$ eV. The band gap of ZnO can be tuned via divalent substitution on the cation site to produce heterostructures. Cd doping can decrease the band gap (to as low as ~3.0 eV), whereas Mg doping can increase the band gap (to as high as ~4.0 eV).

ZnO normally forms in the hexagonal (wurtzite) crystal structure with $a = 3.25$ Å and $c = 5.12$ Å. Electron doping in nominally undoped ZnO has been attributed to Zn interstitials, oxygen vacancies, or hydrogen. The intrinsic defect levels that lead to n-type doping lie approximately 0.01-0.05 eV below the conduction band.

