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Structure, Microstructure and Physicalproperties of ZnO based Materials Invarious Forms : Bulk, Thin film and Nano

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ABSTRACT

ZnO is a unique material that offers about a dozen different applicationpossibilities. In spite of the fact that the ZnO lattice is amenable to metal iondoping (3d and 4f), the physics of doping in ZnO is not completelyunderstood. This paper presents a review of previous research works onZnO and also highlights results of our research activities on ZnO. Thereview pertains to the work on Al and Mg doping for conductivity and bandgap tuning in ZnO followed by a report on transition metal (TM) ion dopedZnO. This review also highlights the work on the transport and opticalstudies of TM ion doped ZnO, nanostructured growth (ZnO polycrystallineand thin films) by different methods and the formation of unique nano- andmicrostructures obtained by pulsed laser deposition and chemical methods.This is followed by results on ZnO encapsulated Fe_3O_4nanoparticles thatshow promising trends suitable for various applications. We have alsoreviewed the non-linear characteristic studies of ZnO based heterostructuresfollowed by an analysis on the work carried out on ZnO based phosphors,which include mainly the nanocrystalline ZnO encapsulated SiO_2,anewclass of phosphor that is suitable for white light emission.

Introduction

Like most other wide band gap semiconductors, ZnO hasalready been studied in the 1970s before being neglected inthe field of microelectronics. The study and growth of thismaterial have been revisited in the past few years because ofits attractive fundamental properties and numerous applicationpossibilities. The technical progress made in synthesis (bulkand nano) and epitaxial growth of thin films and the resultsindicate the possibility of realizing both n-type and p-typeconduction in ZnO [1]. Making p-type ZnO is still a challenge3Author to whom any correspondence should be addressed.and remains an intriguing issue [2,3]. The domains of interestfor compounds based on ZnO and associated heterostructuresare optoelectronics and spintronics. On comparing the keyproperties (table 1) of ZnO with some of the competingcompound semiconductors, it is obvious that there is enormouspotential for ZnO in optoelectronic applications. Indeed ZnOhas a unique combination of high band gap energy (~3.4 eV)and excitonic stability. The high excitonic energy (~60 meV)makes it a potential candidate for light emission applications[4–7]. This also gives strong resistance to high temperatureelectronic degradation during operation (e.g. laser diodes).

Al and Mg doped ZnOProducts such as flat panel displays, solar cells, optoelectronicand electronic components and thermally insulating architec-tural glass have one thing in common. They have a combi-nation of transparency and electrical conductivity. The onlyway to obtain a good transparent conductor is to create electrondegeneracy in a wide band gap (>3eV) oxide by introducingnon-stoichiometry and or by appropriate doping (n- or p-type).It is well known that non-stoichiometric and doped films ofoxides based on, e.g., tin, indium, cadmium, gallium, copper,zinc and their blends exhibit high transmittance and electricalconductivity. The electronic properties of ZnO are of muchimportance in other applications such as transient voltage sup-pressors and ultraviolet protective additives in the manufactureof plastics [36]. Generally, the trivalent elements, such as Al,Ga and B [37], are used as donor dopants in ZnO thin films.ZnO doped with Ga or Al exhibits carrier concentrations of6×1020 cm–3and 7.5×1020 cm–3, respectively [38–41]. Aldoped ZnO samples have been studied extensively till now.Yuan and Cordaro demonstrated the changes in the electronicproperties of Al doped ZnO powders with the help of opticalreflectance characteristics [42]. Hsiao et al [43] synthesizedAl doped ZnO (AZO) nanostructured powders via a spray py-rolysis technique.

Piezoelectric property of ZnO

For creating and designing micro-electromechanical systems(MEMS), new functional materials should be integrated onvarious substrates. Piezoelectric thin films, such as leadzirconate-titanate (PZT), boron doped diamond and oxidizedzinc (ZnO), are the key materials for designing MEMSsyatems. Although the piezoelectric property is of majorimportance for the properties of MEMS, not much attentionwas given to measuring the piezoelectric coefficient of thedeposited thin film. Since the piezoelectric thin film is mostlydeposited by sputtering and sol/gels [98,99], the piezoelectriccoefficient is affected by the deposition conditions to improvethe properties. Very little research work has focused on thematerial composition and deposition conditions. Among theabove-mentioned materials ZnO exhibits both semiconductingand piezoelectric properties that can form the basis forelectromechanically coupled sensors and transducers.

CONCLUSION

In This report the growth of crystalline ZnO, in bulk, thin filmsand nano forms by various chemical and physical techniques,has been presented. A review on the tuning of band gapand resistivity with Mg and Al doping, respectively, waspresented. The key issues for the device application of ZnOin optoelectronics include the growth of high quality layersof n-type conductivity, the possibility of dissolving transitionelements in the lattice and the growth of ZnO nanostructuresand heterostructures, all of which have been featured in thisreview. It is shown that TM-ion doping in ZnO brings about adecrease in electrical resistivity for Fe, Co, Ni, V and Ti dopingand in the case of Cr, Mn doping, resistivity is found to increase.The significant aspects of the PLD technique, such as variousgrowth pressures, substrates and doping, have been specificallyaddressed. Interesting changes in microstructures have beenobserved in TM ion doped ZnO, along with changes in thephysical properties of the parent compound. The possibilityof realizing ZnO based magnetic nanoparticles and phosphorshas also been discussed.

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