Physics Letters A 489 (2023) 129160

Contents lists available at ScienceDirect

Physics Letters A

journal homepage: www.elsevier.com/locate/pla

Letter

Effect of annealing atmosphere on characteristics of kaolin-doped zinc oxide disks

Muna E. Raypah [a], Shahrom Mahmud [b,*], S.A.M. Samsuri [b], Mohd Faizal Jamlos [a,c,*]

[a] Centre of Excellence for Artificial Intelligence & Data Science, Universiti Malaysia Pahang Al-Sultan Abdullah, Gambang 26300, Malaysia
[b] School of Physics, Universiti Sains Malaysia, Pulau Pinang 11800, Malaysia
[c] Faculty of Electrical & Electronics Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Pekan 26600, Malaysia

ARTICLE INFO

Keywords:
Zinc oxide
Kaolin
Disks
Annealing
Electrical properties

ABSTRACT

This study elucidates the effect of the annealing environment (oxygen and nitrogen) on the properties of kaolin-doped ZnO disks. The findings showed that, in comparison to the sample annealed in O_2 ambient, the sample annealed in N_2 has a greater average grain size. The tensile stress, lattice constants, and crystallite size of the (002) plane all indicate that annealing under N_2 enhanced the crystal quality of the ZnO disk. The bandgap energy shifted from 3.09 to 2.96 eV because of the doping and annealing processes. By annealing the kaolin-doped ZnO disk under N_2 atmosphere, the intrinsic defects were almost eliminated. The nonlinear coefficient of the disks varied from 3.6 to 2.0. It was proven in this study that kaolin can be used as an effective dopant/additive for ZnO varistors.

Introduction

ZnO is the most frequently utilized material in the production of metal-oxide varistors [1]. ZnO ceramic varistors are currently employed in the electronics sector (surge protection) due to their superior electrical properties and great energy-handling capacity. ZnO varistor ceramics have outstanding performance in terms of nonlinear electrical properties and the ability to absorb high surge energy. As a result, ZnO varistor ceramics are commonly utilized as surge protection components in electrical systems to protect devices from damage. Following a certain chemical composition and sintering parameters, ZnO varistors are normally manufactured using a traditional method of ceramic processing. Solid-state-based ceramic processing route is the conventional method for manufacturing varistors and is still the preferred method because of its simplicity, cost-effectiveness, and availability of metal oxide additives. In recent years, with the requirement for improved performance of the ZnO varistors, various methods have been reported to advance the homogeneity of the additive powders in order to enhance the material composition. Although there are many different approaches, including sol-gel, hydrothermal, and co-precipitation [2], the conventional approach is far more straightforward, quicker, and simpler to utilize while still providing an adequate output. According to current studies, this technique is still favored and employed with a few modifications to enhance the homogeneity of the microstructure of ZnO-based varistors [3–9].

Despite the focus on high-voltage applications, there is a rising number of varistors that are utilized for low-voltage applications, including mobile electronics, integrated circuits, and automobile electronics [10]. Generally, ZnO varistors are synthesized via sintering/annealing of ZnO disks doped with small quantities of additives/dopants such as Bi2O3, Sb2O3, Co2O3, MnO2, Cr2O3, Al2O3, SiO2, and TiO2 to improve their microstructural quality and electrical performance. Doping will alter the donor density inside ZnO grains, enhance the microstructures and spinel phases, and increase the double Schottky barrier property even more [11]. Si is a recognized dopant that mainly fills cation sites in III-V semiconductors [12] and more defects such as oxygen vacancies will be produced by Si with the highest charge density. Taking into consideration its ion migration capability and relatively small ionic radius, the Si4+ ion can penetrate the lattice structure of ZnO more easily compared to other transition metal ions [13]. On the other hand, Al increases the electrical conductivity of ZnO, thereby enhancing its metallic electrical conduction behavior, and enabling semiconductor-metal transition. The donor density of ZnO increases significantly with Al doping, which concomitantly improves the electrical conductivity of the ZnO grains [14]. Although the advancement made by doping ZnO ceramics with either Al2O3 or SiO2, very few

* Corresponding authors.
E-mail addresses: shahromx@usm.my (S. Mahmud), faizaljamlos@ump.edu.my (M.F. Jamlos).

https://doi.org/10.1016/j.physleta.2023.129160
Received 31 May 2023; Received in revised form 6 October 2023; Accepted 8 October 2023
Available online 10 October 2023