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The Effect of MgO Dopant and Laser Treatment on ZnO Ceramic

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ABSTRACT

ZnO ceramic samples as pellets have been prepared and doped with (1, 2.5, 5, 10 wt%) of MgO powder, sintering at 1300˚C, these samples have been treated with laser at 400 J/cm^2. X-ray diffraction spectra of the samples show some changes in the X-ray parameters, where d-spacing and the intensities of the peaks are changed. FWMH of all the samples was altered due to MgO dopant and the laser influence microstructure was affected by the laser treatment, also, the texture coefficient is affected.

Keywords: ZnO; Laser Treatment; Texture Coefficient; FWMH; X-Ray Diffraction

1. Introduction

Ceramic is an important class of materials which finds increased applications as biomaterials, advanced structural and engineering materials, where surface modifications become important which were greatly influenced by the surface microstructure defined by the morphology and crystallographic texture of the surface grain [1].

ZnO is one of these ceramics with wide band gap semiconductors which is used in optical devices near ultraviolet region.

It has good optical, electrical and piezoelectric properties because it has high transparence in the visible wave length range and low electric resistance and its band gap is 3.3 eV at room temperature [2].

It has been used in many applications such as gas sensors, bulk acoustic wave devices, transparent conductive oxide, solar cell windows besides its applications as biomaterials against bacteria (*i.e.* solution or powders for skin ointment). Many studies have been conducted on laser interaction with ceramic materials, for example, ceramics welding with laser have been studied by Ikeda [3]. For preventing crack for motion at the welded part, a preheating at slow cooling was effective.

Mordike and Sivakumar [4] have used a laser beam to locally melt and densify the ceramic coatings.

Harimkar and Dohotre [5] have discussed the microstructure development during surface modifications of alumina ceramic using high power continuous wave Nd:YAG laser.

Krasnikov *et al*. [6] have been studied the effect of laser treatment with varying pulse duration and pumping voltage on ceramic material. They found the amorphazation of the ceramic structure in the laser beam action zone is established.

Ural *et al.* [7] have studied the effect of laser treatment on the bonding between zirconia ceramic surface and resin cement which has a clear effect on the microstructure of bonding region.

Abeidia *et al*. [8] have studied the realization of molted layers with the CO_2 laser on sintered alumina ceramic.

Dyshlovenko *et al.* [9] have used CO_2 laser to treat plasma sprayed hydroxylapatite coating. The laser beam was scanned with speed of 6.4 mm/s. SEM and X-ray diffraction enabled the determination of quantitative phase composition.

Dimitrov *et al.* [10] have used pulsed laser deposition which can provide crystallization at relatively low substrate temperature due to the higher energy of the ablated particles in the laser—produce plume and relatively high deposition rates.

Adawya *et al*. [11] have studied the deposition of Al_2O_3 on glass substrate by PLD in 10^{-3} m bar oxygen ambient at different alumina concentration with laser fluency energy 0.4 J/cm².

The aim of this work is to study the influence of Nd: YAG laser on the microstructure and morphology of ZnO ceramic with and without MgO.

2. Experimental Procedure

2.1. Materials Used

In the present study, ZnO powder used was obtained from Fluka Company with 99.5% purity, and less than 25% µm particle size MgO obtained from Boh Company with the purity 99.5%, and 25 µm particle size. PVA (poly vinyl alcohol) is used as binder.

2.2. Equipments Used

1) Nd:YAG laser with 400 J/cm².
2) Digital balance (0.0001 gm) sensitivity.
3) Oven type cooper heat.
4) Hydraulic press type (BeGo) capacity 5 tons.
5) Electrical furnace (Ruhs Tral Co.) up to 1350˚C.
6) X-ray diffractions type (XRD 6000 SHIMADZU JAPAN, $\lambda = 1.5405$A˚).
7) Optical microscope type (OLYMPUS OPTICAL Co. LTD. JAPAN).

2.3. Samples Preparation

ZnO powder mixed thoroughly with 1.5% of PVA as a binding material and pressed at 3 tons as a disc of 10 mm diameter and 4mm thickness.

Other samples contain four percentages of MgO (1 wt%, 2.5 wt%, 5 wt% and 10 wt%) mixed and pressed as the same above procedure.

All the samples dried at 80˚C in an oven for six hours and then sintered in an electrical furnace at 1300˚C with 5˚C/min as a heating rate for 2 hrs and then cooling at the same rate. All the samples have been treated with pulsed laser.

3. Results and Discussion

3.1. Analysis of X-Ray Spectra

Laser surface modification of ZnO and ZnO doped MgO ceramics with the range of laser influence (400 J/cm²) employed in the present study.

X-ray diffraction patterns obtained at room temperature for ZnO sample before and after laser treatment are shown in **Figures 1** and **2**.

After treatment, there was a change in the intensities of the peaks with sharp altitude, also shift slightly towards high 2θ values which mean the d-spacing values are decreased.

Figures 3-10 show the X-ray spectra of ZnO doped

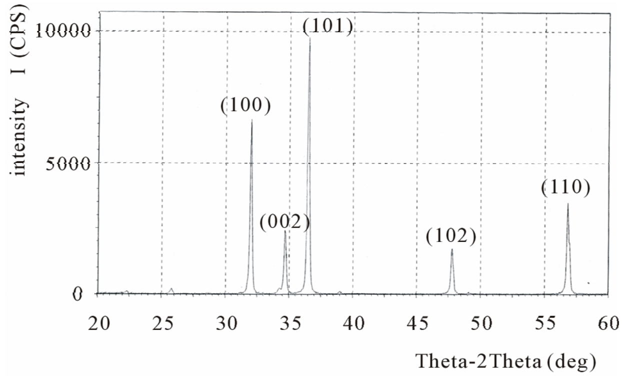


Figure 1. XRD Spctrum of pure ZnO.

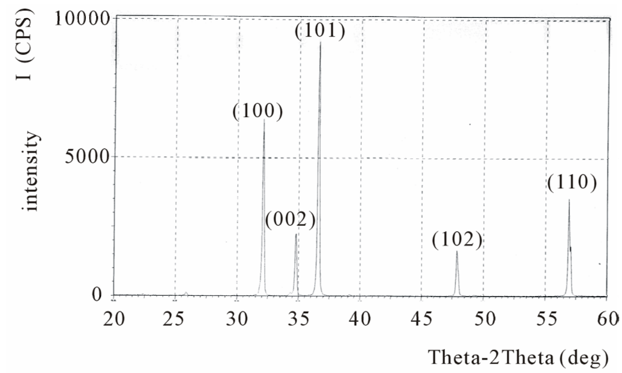


Figure 2. XRD Spctrum of treated ZnO by Laser.

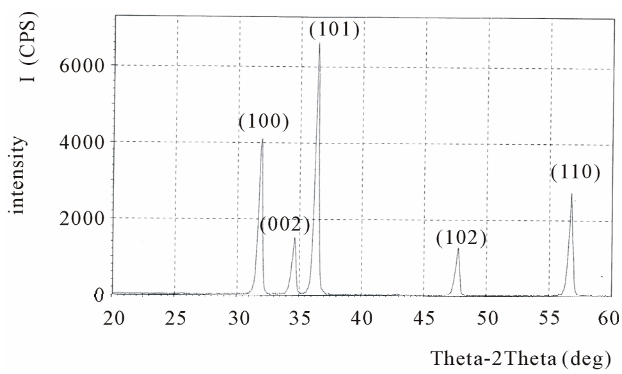


Figure 3. XRD of ZnO doped with 1 wt% MgO sintered at 1300˚C.

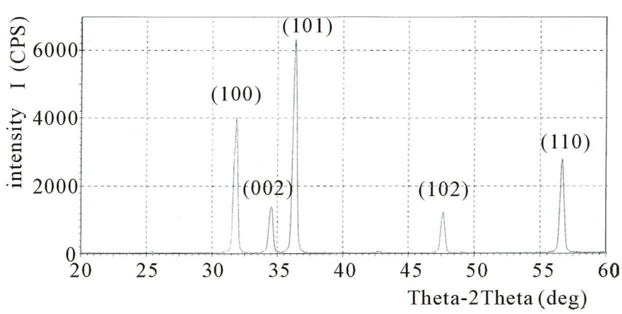


Figure 4. XRD Spectrum of ZnO 1 wt% MgO treated by Laser.

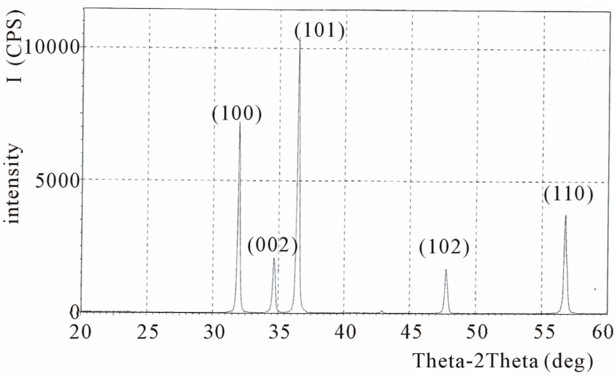


Figure 5. XRD Spectrum of ZnO 2.5 wt% MgO.

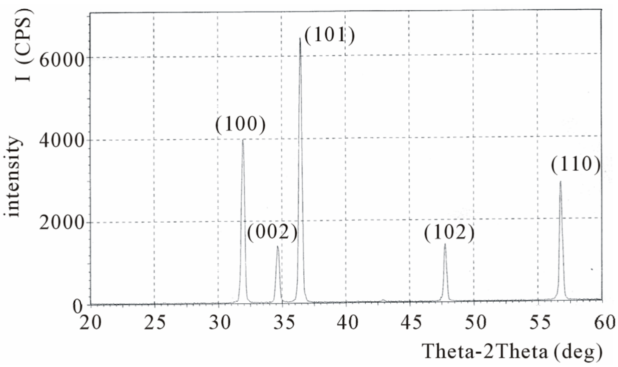


Figure 6. XRD Spectrum of treated ZnO 2.5 wt% MgO.

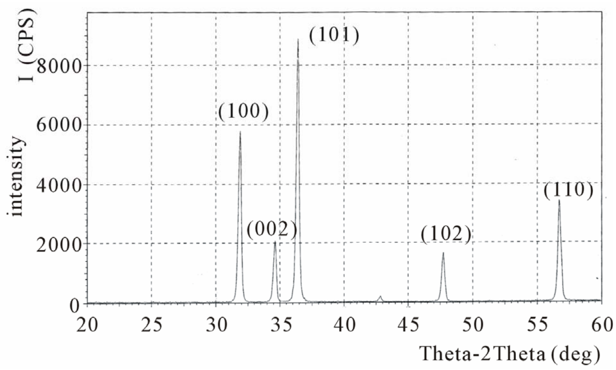


Figure 7. XRD Spectrum of ZnO 5 wt% MgO.

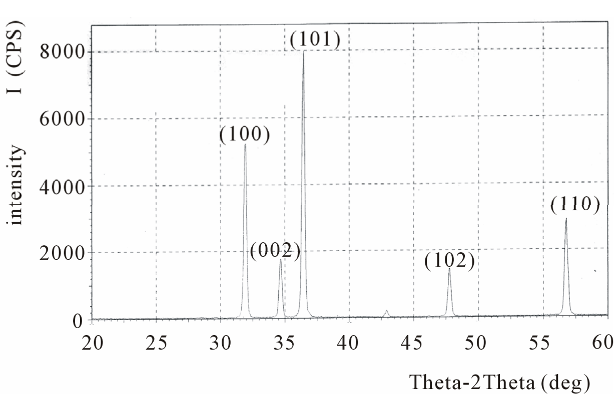


Figure 8. XRD Spectrum of treated ZnO 5 wt% MgO.

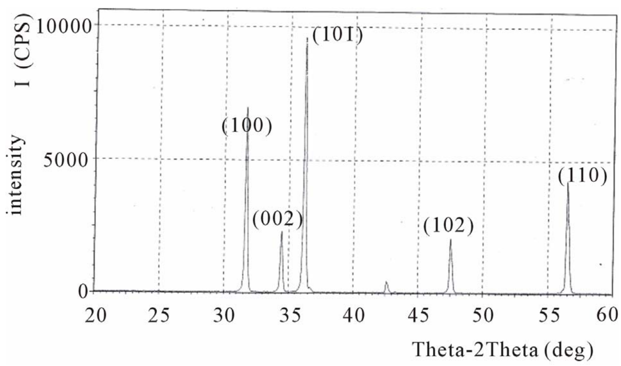


Figure 9. XRD Spectrum of ZnO 10 wt% MgO.

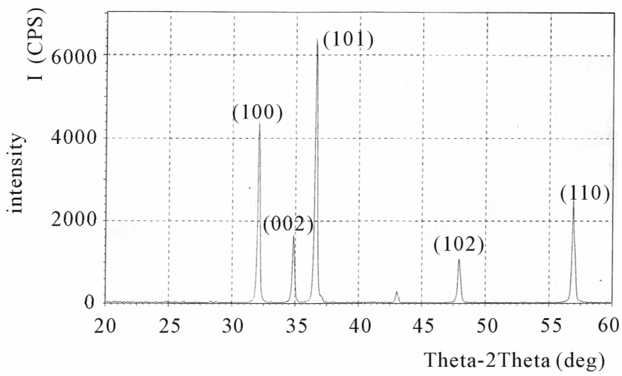


Figure 10. XRD Spectrum of ZnO 10 wt% MgO treated by Laser.

with different percentages of MgO (1 wt%, 2.5 wt%, 5 wt% and 10 wt%) before and after treatment by laser. At 1 wt% MgO dopant it is cleared that d-spacing is increased by introducing the MgO oxide and the altitude of peak intensities is increased again and the d-spacing values decreased at the laser treatment, but still higher than those of pure ZnO as shown in **Figure 4**.

At 2.5 wt% MgO again sharp and high altitude of peaks have shown with decreasing in d-spacing but after treatment with laser the change in d-spacing values are small with sharp peaks as shown in **Figure 6**.

Increasing the doping to 5 wt% MgO high peaks intensities observed and the d-spacing values are decreased sharply as shown in **Figure 7**. **Figure 8** shows the spectra of laser treatment of the samples have sharp peaks and high intensities are observed with decreasing in d-spacing values.

A small intensity peak at 2θ equal 43.04 appeared in this spectra which is belong to MgO according to N 1997 JCPAS No. 45-0946.

Figure 9 shows the spectra of 10 wt% MgO which has very sharp peak with high intensity and high d-spacing values , but at the treatment with laser the intensities are decreased slightly with decreasing of d-spacing values , a new peak with 2θ equal 42.63 which belong to MgO observed with slight high intensity in **Figure 10**.

In general, the analysis of X-ray spectra revealed a systematic variation of relative intensities and d-spacing values for all the spectra planes with MgO dopant and laser influence.

3.2. Analysis of Texture Coefficient

Figure 11 shows the values of FWHM for all the samples which show that the addition of MgO is increased the value of FWHM and the maximum is at 1 wt% and then decreased, with treated the samples by laser the value of pure ZnO is increased and the same behavior with the doping of MgO.

The development of texture with the laser influence can be quantified in terms of the texture coefficient (TC) given by [3]:

$$Tc(hkl) = \frac{I(hkl)}{I_0(hkl)}\left\{\frac{1}{n}\sum\frac{I(hkl)}{I_0(hkl)}\right\}^{-1}$$

where $I(hkl)$ are measured intensities of (hkl) reflection, $I_0(hkl)$ are powder reflection intensities of ZnO according to ICDD PDF ≠ 36 - 1451 and (n)is the number of reflections used in the calculation.

Following (hkl) reflections corresponding (100,002, 101,102,110) of the samples the results of TC calculation for (100) reflection are presented in **Figure 12**.

The figure indicates that the TC increased gradually with increasing MgO content which reached maximum value at 2.5 wt% and then decreased progressively; thus substantiating the formation of strong (100) texture at the intermediate MgO content, these two regimes of explored MgO contained less and greater than 2.5 wt%. The variation of TCs and the relative intensity of (100) plane corresponding closely with the regimes of MgO content and laser influence which showed a distinct variation in the morphology of surface grains in laser surface modified ZnO ceramic as shown in **Figure 12**.

3.3. Analysis of Microstructures

The effect of laser irradiation on the surface microstructure of ZnO and ZnO doped MgO are illustrated in **Figures 13-17**. These figures present a set of optical surface images which represent the untreated and treated samples at laser influence of 400 J/cm².

The untreated samples consisted of irregular ZnO and MgO grains with a degree of interconnected porosity.

It is evident that the surface microstructure of laser modified ZnO ceramic is characterized by faceted polygonal surface grains with varying size and the extension of surface faceting depend on MgO contend and laser influence.

Some of the surface grains tend to deviate from polygonal shapes transferred from irregular to near circular shapes.

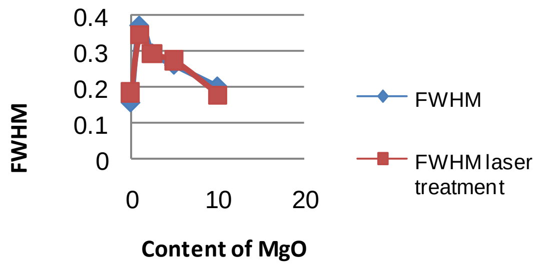


Figure 11. Variation of (100) FWHM of untreated and treated samples with laser influences.

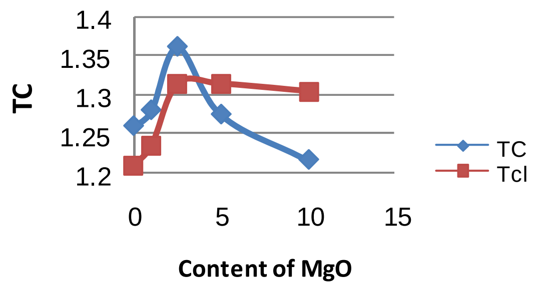
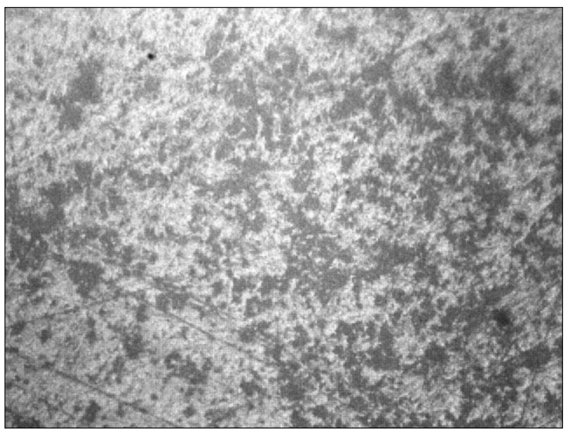
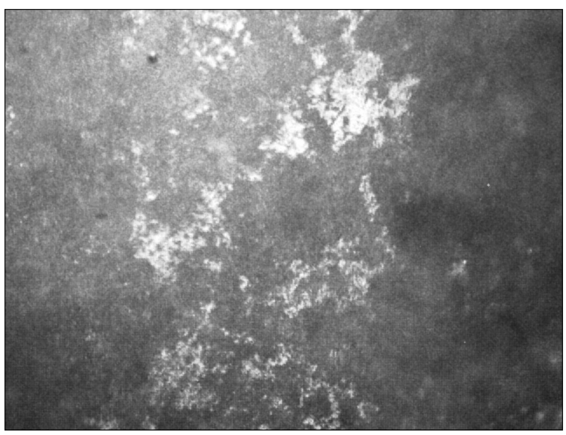


Figure 12. Variation of (100) TC of untreated and treated samples with laser influences.

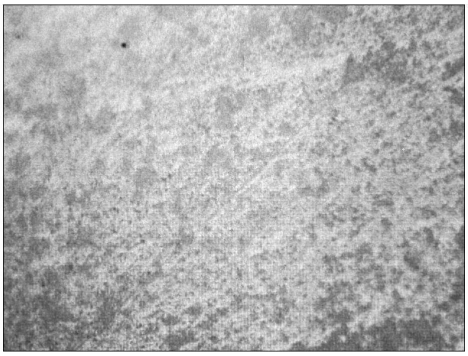


(a)

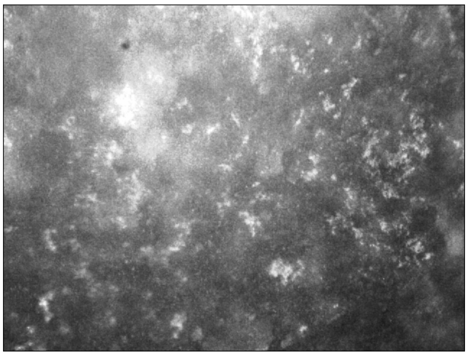


(b)

Figure 13. Micrograph optical microscope of (a) untreated and (b) laser treated of pure ZnO.

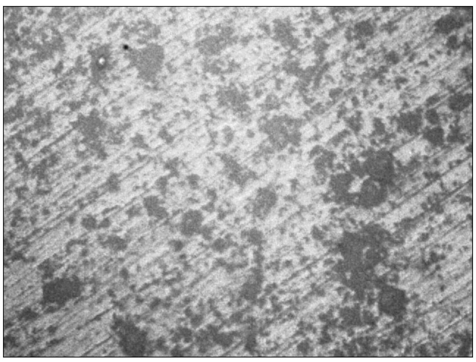


(a)

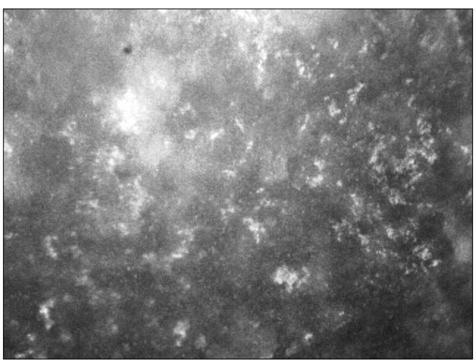


(b)

Figure 14. Micrograph optical microscope of (a) untreated and (b) laser treated of ZnO with 1 wt% MgO.

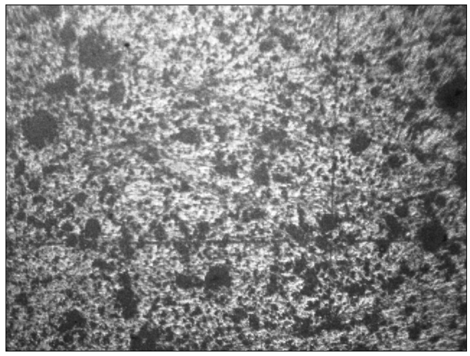


(a)

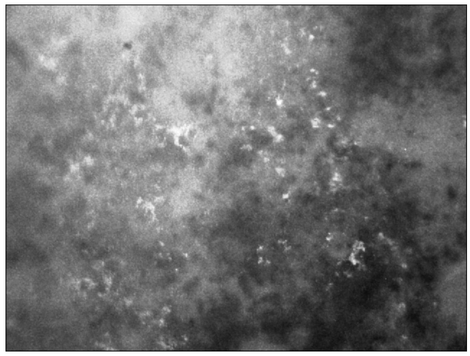


(b)

Figure 15. Micrograph optical microscope of (a) untreated and (b) treated ZnO with 2.5 wt% MgO.

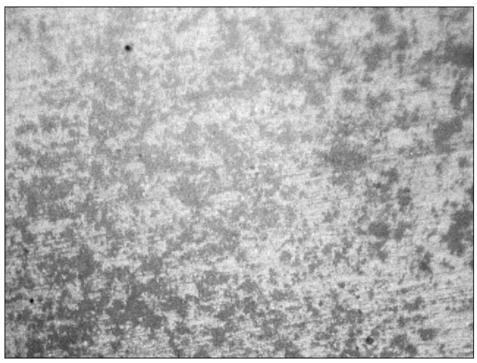


(a)

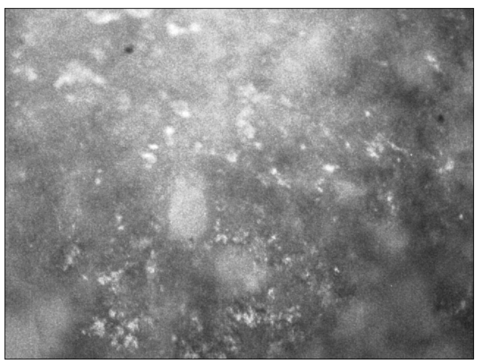


(b)

Figure 16. Micrograph optical microscope of (a) untreated and (b) laser treated of ZnO with 5 wt% MgO.



(a)



(b)

Figure 17. Micrograph optical microscope of (a) untreated and (b) laser treated of ZnO with 10 wt% MgO.

4. Conclusions

Laser surface modifications of ZnO ceramic and ZnO doped with different percentages of MgO with Nd-YAG laser results in the formation of surface microstructure consisted of faceted surface grain have been observed.

MgO dopant and laser influence have changed the parameters of microstructure of ZnO such as FWHM, d-spacing, 2θ and intensities of the peaks besides the texture coefficient (TC)n.

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