UNIVERSITY OF BELGRADE

TECHNICAL FACULTY BOR

52nd International October Conference on Mining and Metallurgy

PROCEEDINGS

Edited by

Saša Stojadinović

and

Dejan Petrović

November 29th – 30th 2021

Bor, Serbia

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SEM AND X-RAY ANALYSES OF SINTERED MgO / Bi_2O_3BINARY SYSTEM

Nataša Đorđević[1], Slavica Mihajlović[1], Miroslav Sokić[1], Branislav Marković[1]
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Abstract
Magnesium oxide is a component of many ceramic materials. Bismuth oxide is added as an additive to ceramic materials in order to lower the sintering temperature. The influence of temperature was researched by sintering binary system: MgO/Bi_2O_3.The temperature of process was 820 °C and 1100 °C. Composition of this system was 80% of MgO and 20% Bi_2O_3. The effects of sintering, the composition and morphology were followed by X-ray diffraction and Scanning electron microscopy. It has been found that Bi_2O_3 forms intermediary unstable compound with MgO.

Keywords:MgO, Bi_2O_3, sintering, SEM, x-ray analysis.

1. INTRODUCTION

These studies were performed in order to determine the influence of bismuth oxide on the sintering process of ceramic materials and the possibility of reaction during sintering with magnesium oxide as one of the components of the system.

One of the most important ceramic materials whose composition includes magnesium oxide is cordierite. Its composition is $2MgO*2Al_2O_3*5SiO_2$. Since the temperature range of cordierite sintering is very narrow (sintered temperature is 1300 – 1400 °C), the techniques of lowering the temperature of its formation are very interesting for research.

As the melting point of bismuth oxide is 750 °C, adding the cordierite mixture during the sintering process is the expected result of lowering the sintering temperature due to the formation of a two-phase system. During sintering, it is possible to form intermediate compounds of additives with system components, which was the aim of this research.

2. EXPERIMENTAL

During this research following components were used: MgO (Euro Hemija, Beograd), Al_2O_3 (Aluminijumskikombinat, Podgorica), SiO_2 (Bela Reka) and Bi_2O_3, p.a. (Reahim, Rusia). Chemical composition of starting compounds is given in Table 1.

Following mixture was prepared: MgO/Bi_2O_3, in relation 80% of magnesium oxide and 10% of Bi_2O_3. Samples for sintering were prepared in the tablet shape, with radius 8mm and height 4mm, under the pressure of 1 t/cm^2. Sintering temperature of the sample MgO/Bi_2O_3 was 820 °C and 1100 °C.

X-ray powder diffraction (XRPD) technique was used for identification and definition of the unit-cell parameters. XRPD analysis was performed using the Philips PW1710 diffractometer; with Cu Kα radiation (40kV, 30mA), step scan 0.25s, 0.02° 2θ, *d* range from 5° to 85°2θ. The microstructures of the sintered samples were observed using scanning electron micrograph (SEM) with microsonde.

3. RESULTS AND DISCUSSION

Sample MgO/Bi_2O_3, sintered at 820°C (Fig.1.) showed very low level of crystallinity. Following compounds were detected: periclase (MgO), bizmite (α-Bi_2O_3) and silenite (γ-Bi_2O_3). Under these conditions, only Bi_2O_3 was phase transformed, other phases were not formed since this temperature was too low for any other transformations. In the sample MgO/Bi_2O_3 after sintering at 1100°C, periclase (MgO), mixture of bismuth oxide (α, β and γ Bi_2O_3) and unstable compound - $Bi_{12}MgO_{19}$ were found.

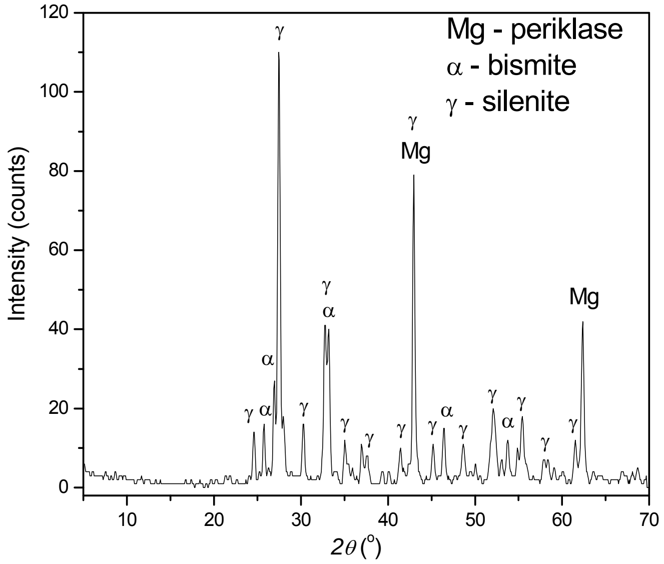

Figure 1. X-ray diffraction patterns of the sample MgO/Bi_2O_3 sintered at 820°C

SEM microphotograph of the sample MgO/Bi_2O_3, (Fig.2) sintered at 820°C, is shown in the Figure 3. The grains with flat surface could be notice. With the magnification of 2000X the pyramidal structure (5-10μm) and microstructure with spherical shape (dimension 100-400nm) are visible.

The microphotographs of the samples sintered at 1100°C are morphologically different from the sample sintered at 820°C. Small-grain structure of the crystal (visible with magnification of 25000X and pointed to initial sintering), by this microphotograph is well visible (Figure 4). The grains sizes ~100nm at 820 °C after sintering at 1100 °C have dimensions sized in μm. Pyramidal structure could not be founded in this sample.

Crystals are isometrics, enhydral. The grains are rounded, well developed, clearly visible, with diameter of ~ 1μm, symmetrically formed, flat surface boarded.

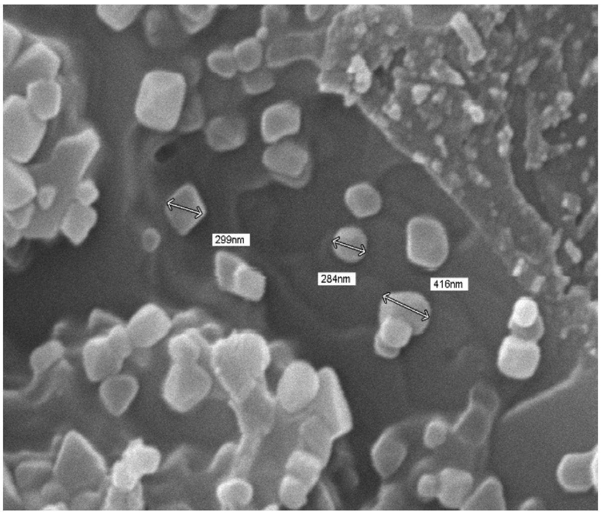

Figure 2. SEM microphotographs of the sample MgO/Bi_2O_3 sintered at 820^oC (3000 X)

SEM microphotograph of the sample MgO/Bi_2O_3, (Fig.2) sintered at 820^oC, is shown in theFigure 3. The grains with flat surface could be notice. With the magnification of 2000X the pyramidal structure (5-10μm) and microstructure with spherical shape (dimension 100-400nm) are visible.

The microphotographs of the samples sintered at 1100^oC are morphologically different from the sample sintered at 820^oC. Small-grain structure of the crystal (visible with magnification of 25000X and pointed to initial sintering), by this microphotograph is well visible (Figure 4). The grains sizes ~100nm at 820 °C after sintering at 1100 ^oC have dimensions sized in μm. Pyramidal structure could not be founded in this sample.

Crystals are isometrics, enhydral. The grains are rounded, well developed, clearly visible, with diameter of ~ 1μm, symmetrically formed, flat surface boarded.

4. CONCLUSIONS

In the aim of researching the reactions of cordierite synthesis, the binary systems were examined as follows: MgO/Bi_2O_3 sintered at 820ºC and 1100ºC. The results showed liquid phase in the system at 820ºC (the melting temperature of Bi_2O_3) and producing meta-stable compounds that form MgO with Bi_2O_3 at 1100ºC. This unstable compound transports through the liquid phase, which allowed (from the two aspects) the acceleration of the reaction in the more-component system.

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REFERENCES

[1] N. Djordjevic, Lj. Pavlovic, "The Influence of Activation and Relaxation Time on the Synthesis of Cordierite Ceramics", J. Serb. Chem. Soc, Vol. 71,No. 3, pp. 293-301, 2006.

[2] N. Obradović, N. Đorđević, S. Filipović, N. Nikolić, D. Kosanović, M. Mitrić, S. Marković, V. Pavlović, Influence of Mechanochemical Activation on the Sintering of Cordierite Ceramics in the Presence of Bi_2O_3 as a Functional Additive, Powder Technology 218 pp. 157–161, 2012.

[3] N. Obradovic, S. Stevanovic, M. Mitric, M. V. Nikolic, M. M. Ristic, Science of Sintering, 39 2007 p.241.

[4] N.Obradović,V.Blagojević,S.Filipović,N.Đorđević,D.Kosanović,S.Marković, M.Kachlik,K.Maca, V.Pavlović, Kinetics of thermally activated processes in cordierite-based ceramics, Journal of Thermal Analysis and Calorimetry138,2019p2989–2998

[5] Obradović N, Đorđević N, Filipović S, Nikolić N, Kosanović D, Mitrić M, Marković S, Pavlović V. Influence of mechanochemical activation on the sintering of cordierite ceramics in the presence of Bi_2O_3as a functional additive. Powder Technol. 2182012, p.157–61.