PHASE INVERSIONS IN Al-Si-Mg GELS. INFLUENCE OF Ti, Ce, AND Zr ADDITIONS

A. V. Galakhov, V. Ya. Shevchenko, and A. A. Stebunov

The sintering temperature of cordierite (2Al2O3·2MgO·5SiO2) made from natural minerals is 1300-1410°C [1]. Using synthetic powders obtained with the sol-gel method reduces the sintering temperature to 800-900°C [2]. When amorphous Al-Si-Mg gel of cordierite composition is heated at 1000-1100°C, a phase known as μ-cordierite [3] is formed (hexagonal, spatial group P622), or as the quartz-like phase [4]. At 1100-1250°C this phase changes into β-cordierite (hexagonal, spatial group P6/mcc) which upon further increase in temperature is gradually transformed into α-cordierite (orthorhombic, spatial group Cccm). From research into the phase inversions in Al-Si-Mg glasses, it is known that the use of TiO2, ZrO2, and CeO2 additives [5] reduces the crystallization temperature of cordierite. The present article presents the results of a study of the influence of such additives on the phase changes in powdered cordierite compositions obtained by the sol-gel method.

Tetraethoxysilane (TEOS) was used as the starting point for obtaining Al-Mg-Si gels (special purity grade); and also Al(NO3)3·9H2O (chemically pure), Mg(NO3)2·6H2O (analytical purity), Ce(NO)3 (analytical purity), ZrOCl2·8H2O, and TiCl3 (pure, 20% alcoholic solution). The hydrated aluminum and magnesium nitrates were dissolved in absolute ethyl alcohol in the ratio Al3+:Mg2+ = 2:1. To the salt solution was then added the tetraethoxysilane in an amount to obtain the composition 2Al2O3·2MgO·5SiO2. Additions in the form of hydrated salts of Ce, Zr, or a solution of TiCl3 in amounts (calculated as the oxide) of 5% mass were incorporated at the stage of preparing the alcoholic solution of aluminum and magnesium salts. After adding the TEOS and a 30-min mixing, the solutions were placed in a thermostat and heated to 60°C. The gel-forming time for all compositions was approximately the same, i.e., about 4 h. Gels were transparent and of a vitreous appearance. They were dried at 100°C, and then heat-

![Graph](image-url)
Fig. 2. X-rays for Al-Si-Mg gels after 3 h heating: temperature, °C: 1) 700; 2) 900; 3) 1000; 4) 1100; 5) 1200; 6) 1300; μ - μ-cordierite, β - β-cordierite, α - α-cordierite, P - petalite phase, T - zirconium dioxide (tetragonal), M - zirconium dioxide (monoclinic), ZS - zircon, C - cerium dioxide.