Sintering and some Properties of Si$_3$N$_4$ Based Ceramics

S. BOSKOVIĆ AND E. KOSTIĆ

'Boris Kidrič' Institute of Nuclear Sciences, POB 522, Lab. 170, 11001 Belgrade, Yugoslavia

ABSTRACT

Sintering of Si$_3$N$_4$ was investigated in the temperature range 1550–1750°C. As additions which promote sintering of Si$_3$N$_4$ the following were used:

- $Y_2O_3$, a mixture of $Y_2O_3 + Al_2O_3$, and the four component mixtures:
  - $Y_2O_3 + Al_2O_3 + AlN + Si_3N_4$,
  - $YAG + Al_2O_3 + AlN + Si_3N_4$,
  - $DyAG + Al_2O_3 + AlN + Si_3N_4$.

By using these additions, dense Si$_3$N$_4$ ceramics were obtained at 1750°C. Special attention was paid to phase composition of sintered samples which depends on the additive which allows sintering to take place. Furthermore, thermal treatment of some samples was performed at 1450°C with the intention of decreasing the amount of glassy phase formed during sintering. Changes of hardness, density and toughness were determined as a function of thermal treatment time.

1. INTRODUCTION

Silicon nitride is known to have excellent mechanical properties, especially high toughness. However, the hardness of this ceramic is no better than that of Al$_2$O$_3$. A number of investigations have been concerned with finding good additions which would increase the hardness of the material. On the other hand, these additives must fulfil
another important condition, that is, to enable the densification of Si₃N₄ by liquid phase formation. Y₂O₃ and Y₂O₃ + Al₂O₃ are additions most commonly used for this purpose.¹,²

This paper also describes the use of the additions Y₂O₃ and Y₂O₃ + Al₂O₃ to silicon nitride and compares the four-component mixtures Y₃AlN + Al₂O₃ + Si₃N₄; DyAl₃G + Al₂O₃ + Al₂O₃ + Si₃N₄; and Y₂O₃ + Al₂O₃ + Al₂O₃ + Si₃N₄ which will promote densification. Depending on additive composition, two kinds of ceramic, β-Si₃N₄ and β'-SiAlON were synthesized.

2. EXPERIMENTAL

α-Si₃N₄ powder was supplied by Starck, West Germany, with a specific surface area of 8 m² g⁻¹. The additives used were (wt %):

A₁: 10% Y₂O₃  
A₂: 6% Y₂O₃ + 2% Al₂O₃  
A₃: 5% Y₂O₃ + 5% Al₂O₃  
A₄: 10% Y₂O₃ + 5% Al₂O₃  
A₅: 10% Y₂O₃ + 10% Al₂O₃  
B₁: 72% YAG + 6% Al₂O₃ + 12·8% Al₂O₃ + 9·2% Si₃N₄  
B₂: 72% DyAG + 6% Al₂O₃ + 12·8% Al₂O₃ + 9·2% Si₃N₄  
B₃: 41·2% Y₂O₃ + 43·6% Al₂O₃ + 6% Al₂O₃ + 9·2% Si₃N₄

Liquid formation occurs below 1550°C.

Homogenization of α-Si₃N₄ with previously homogenized mixtures was performed in isopropyl alcohol. Green pellets were isostatically pressed under 147 MPa. Sintering was carried out in the temperature range 1450–1750°C for 1 hour with the pellets packed in a powder bed of the same composition.

3. RESULTS AND DISCUSSION

Additions which promote sintering of Si₃N₄ in the presence of the liquid phase bring about chemical reaction development. By choosing appropriate compositions of additions, either β-Si₃N₄ or β'-SiAlON can be produced as a major phase within the material.

For consolidation of Si₃N₄ the volume of liquid as well as its