HIGH PERFORMANCE SILICON NITRITE COMPOSITE CERAMICS THROUGH GRAIN BOUNDARY AND MICROSTRUCTURAL TAILORING

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KEYWORDS / ABSTRACT: Si₃N₄ Ceramics / High Temperature Performance / α,β-Sialon Composite / Grain Boundary Engineering

The potential of improving the high temperature performance of nitride ceramics will be illustrated through two different routes. The first is based on β-Si₃N₄ matrixed material by tailoring the grain boundary phase that is highly refractory both in the glassy state and in the partially devitrified state. Good high temperature mechanical properties have been obtained up to 1300-1400°C. The second is to tailor the microstructure of α'/β'-Sialon composite material with Y₃Al₅O₁₂ as the grain boundary phase through processing. The results clearly indicate the role that processing and microstructure can play to influence the high temperature properties.

INTRODUCTION

Silicon nitride ceramics constitutes a family of materials that has gained increasingly keen concern in the past couple of decades as structural engineering materials because of its high strength, good toughness, low density and high anti-wear properties etc. Another important aspect that is worthy of mentioning, is that silicon and nitrogen as natural resources are almost unlimited. the large number of publication in recent years is a good indication of the growing interest in the materials community both from the academic side and from the exploration of its practical, high performance applications. The scale of commercial production of silicon nitride materials has been on the rise by penetrating into a number of important fields of application at temperature ranges up to around 1000°C[1,2] However, its potential serviceability at higher temperature ranges will be even more attractive, since there are very few material categories that can be considered for long-duration application at temperatures of say, 1200-1300°C and beyond. Many high-tech fields ask for such materials and the benefit which can be gained by uplifting the operation temperatures will be tremendous. For instance, the gas inlet
temperature dictating the efficiency of a heat engine is a well-known problem which is actually limited by the high temperature metal alloy materials available today.

On this context, it is very timely for the MP-Institute for Metal Research to organize this Workshop to discuss this issue in depth. For silicon nitride materials, while entering into this high temperature regime of performance surely there are a host of problems that are still not clear or not well understood. I wish to thank the organizers of the Workshop for inviting me to this beautiful place to share our experiences from various aspects and I am sure that there will be very fruitful discussions.

In this talk, I will first review some of our earlier works based on $\beta'$-Sialon with refractory grain boundary phase(s) both at the as-sintered state and at the devitrified state. And in the second part, some recent results on $\alpha'$+$\beta'$-Sialon composites with tailored grain boundary phases through processing will be presented.

COMPOSITIONAL CONSIDERATIONS FROM OUR KNOWLEDGE ON RELEVANT PHASE EQUILIBRIUM RELATIONSHIPS

A lot of effort has been put in in the study of the phase equilibrium relationships of M-Si-Al-O-N systems (M=Na, Li, Mg, Ca, Y and rare earth elements)\[^{3-19}\] by a number of laboratories. The significance of such studies is to provide information for: (a) guiding the selection of effective sintering aids to achieve densification; (b) the control and tailoring of grain boundary phase(s); and (c) the design of nitride ceramics with composite Sialon major phases.

For the two types of silicon nitride materials to be discussed in this talk, the relevant systems involved are the Y-La-Si-O-N system and the Y(Re)-Si-Al-O-N system.

\[Y_2O_3\] and \[Al_2O_3\] compound additives are now commonly used to fabricate silicon nitride ceramics with good properties and have been produced as commercial products (e.g. PY6 of former GTE and Syalon 201 of Cookson). However, with the surface SiO$_2$ present along with silicon nitride starting powders, the lowest eutectic temperature of SiO$_2$-Al$_2$O$_3$-Y$_2$O$_3$ system is not high. Therefore, these materials are good to be used at temperatures below 1000°C and the mechanical strength generally degrades rather significantly beyond 1000°C. By

![Fig.1 Sub-solidus phase relationships in the system Si-Y-La-O-N](image-url)