HIGH TOUGHNESS HIGH STRENGTH SiAlON CERAMICS

Silicon nitride and SiAlONs are the materials possessing unique combination of fracture toughness, hardness and strength and have potentials to be used in many industries. A strive to further increase the reliability of these ceramics lead to the use of many sintering aids and densification methods involving pressure and pressureless sintering. The problem associated with fabrication of these ceramics has been how to impart high fracture toughness and, at the same time, retain high hardness and strength.

The key microstructural feature that controls the strength and toughness of SiAlON ceramics is the α→β phase transformation that takes place during densification at high temperature. This transformation is accompanied by a growth of elongated β-phase at the expense of equiaxed α-phase, as shown in Fig. 1 below.

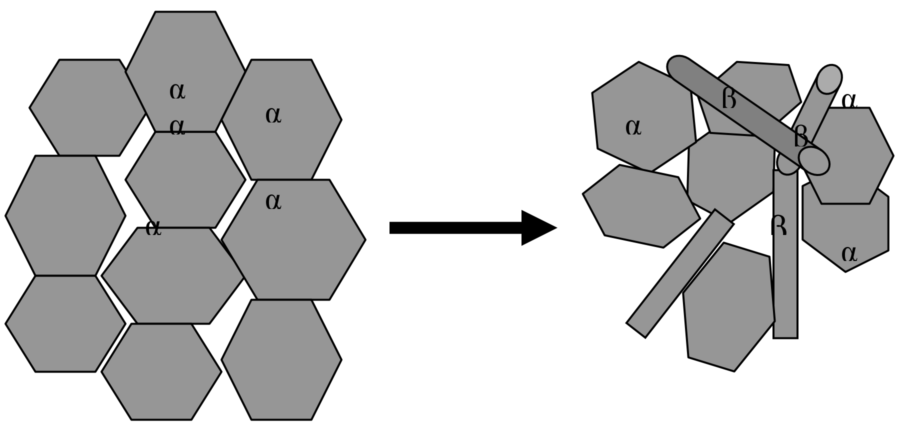

Fig. 1 Transformation of α- to β-Si_3N_4 during sintering high temperature

It has been discovered that that, in order to impart high fracture toughness and strength, the shape of the transformed β-Si_3N_4 grains must remain small in diameter and high in length with circular cross-section rather then rectangular cross-section. This new whisker-like structure is presented in Fig.2 below. With this microstructure it is possible to fabricate ceramics with outstanding combination of fracture toughness and hardness not found in other ceramics. The example of such structure is shown in Fig. 2 for samples sintered to high density.

Instead of plate form grain commonly observed in this type of ceramics, the new SiAlON ceramics contains rod or whisker type β-SiAlON grains with diameter ranging from 1-2 µm and the aspect ration ranging from 6 to 12.

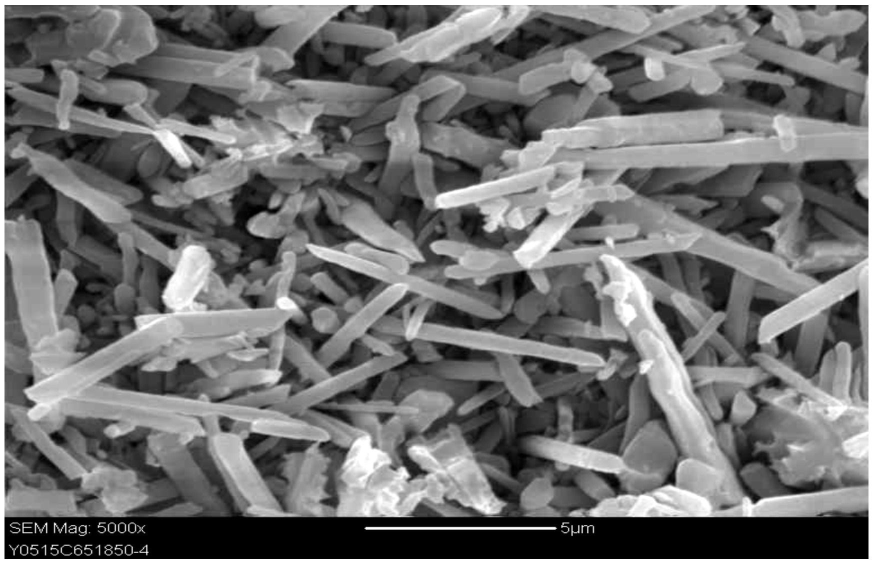

Fig. 2 SEM Micrograph of a whisker-like structure of a new generation of SiAlON ceramic produced by www.sialon.com and partners.

This type of microstructure provides combination of high fracture toughness and hardness (Table I) not found in commercially available materials. High fracture toughness and high hardness make this class of ceramics suitable for applications where only metals and composite are used, including cutting tools for machining steel and nonferrous alloys, engine components and parts in metals smelting industries. Tests have shown this ceramic to exhibit excellent performance in cutting operation against cast iron and steel and serves as a substitute for alumina-whiskers cutting toll with added advantage of having increased inertness in contact with iron during high speed cutting. In addition to inadequate fracture toughness and hardness of classical silicon nitride ceramics, high reactivity with work-piece has been the main problem facing the existing silicon nitride-based ceramics in cutting operations. Reaction-assisted wear of the tool during machining of steel was the largest impediment for the wider use of silicon nitride as tool material in machining steel and nonferrous alloys.

The new generation of SiAlON ceramics developed by www.sialon.com and partners has shown to significantly improve the shock resistance and decrease wetting by molten aluminum, making it highly attractive for the fabrication of crucibles, tubes and fixtures used in metal smelting operations.

Table I: Comparison of mechanical properties of pressureless sintered SiAlON and hot-pressed alumina-silicon carbide whiskers composites

Cutting Tools Insert	**Fracture Toughness K_{IC} ($MPa \cdot m^{1/2}$)**	**Hardness (GPa)**
Cutting tool insert based on *SiAlON* 	**8.76**	**16.87**
Cutting tool insert based on Alumina-silicon nitride whiskers 	**7.47**	**17.36**

Other qualities of SiAlONs and silicon nitride ceramics are presented in Table II.

Table II: Density, hardness and fracture toughness of various grades of SiAlON and silicon nitride ceramics manufactured by www.sialon.com and partners.

Sample	ALU 1	ALU 2	ALU 3	ALU 4	ALU 5
Theoretical Density %	99.7	99.4	99.7	98.8	98.4
Hardness H_V, GPa	15.42	14.94	14.83	13.2	17.79
K_{IC}, MPa.m$^{1/2}$	8.01	8.27	8.55	10.2	7.36