



INTERNATIONAL  
**Syalons**

**HIGH PERFORMANCE  
ADVANCED CERAMICS**

## What are Sialon Ceramics?

**Sialons are ceramic alloys** based on the elements **silicon (Si)**, **aluminium (Al)**, **oxygen (O)** and **nitrogen (N)** and were developed in the 1970s to solve the problem of silicon nitride ( $\text{Si}_3\text{N}_4$ ) being difficult to fabricate.

As alloys of  $\text{Si}_3\text{N}_4$ , sialons exist in three basic forms. Each form is iso-structural with one of the two common forms of  $\text{Si}_3\text{N}_4$ , beta ( $\beta$ ) and alpha ( $\alpha$ ) and with silicon oxynitride. The relationship between that of sialon and  $\text{Si}_3\text{N}_4$  is similar to that between brass and pure copper. In the later case, copper atoms are replaced by zinc to give a better and stronger alloy than the mother metal. In the case of sialon, there is substitution of Si by Al with corresponding atomic replacement of N by O, to satisfy valency requirements. The resulting 'solution' (sialon) has superior properties to the original pure solvent (silicon nitride).

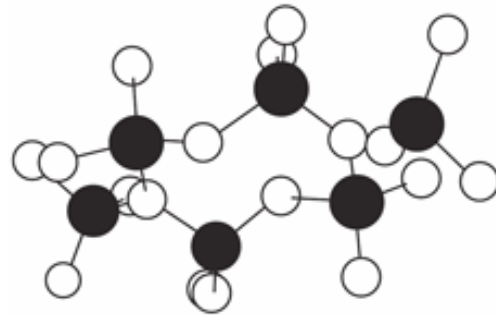
### $\beta$ -Sialon

$\beta$ -sialon is based upon the atomic arrangement existing in  $\beta$ - $\text{Si}_3\text{N}_4$ . In this material, Si is substituted by Al with corresponding replacement of N by O. In this way up to two-thirds of the silicon in  $\beta$ - $\text{Si}_3\text{N}_4$  can be replaced by Al without causing a change in structure. The chemical replacement is one of changing Si-N bonds for Al-O bonds. The bond lengths are about the same for the two cases but the Al-O bond strength is significantly higher than that of Si-N. In sialon the Al is co-ordinated as  $\text{AlO}_4$  and not as  $\text{AlO}_6$  as in alumina ( $\text{Al}_2\text{O}_3$ ). Therefore, in  $\beta$ -sialon the bond strength is 50% stronger than in  $\text{Al}_2\text{O}_3$ . Thus sialons intrinsically have better properties than both  $\text{Si}_3\text{N}_4$  and  $\text{Al}_2\text{O}_3$ .



$\beta$ -sialon is produced by **International Syalons** using yttrium oxide ( $\text{Y}_2\text{O}_3$ ) as a sintering aid and

The fundamental structural unit of  $\text{Si}_3\text{N}_4$  is the  $\text{SiN}_4$  tetrahedron, which is analogous to the  $\text{SiO}_4$  structural units in silicates. The tetrahedra are linked together into a rigid three dimensional framework by sharing corners. The Si-N bonds are short and they are very strong. This strong, rigid, compact structure is responsible for many of the important properties of  $\text{Si}_3\text{N}_4$ .



marketed under the trade name **Syalon 101**. During sintering, at temperatures above  $1400^\circ\text{C}$ , the oxides react to form an yttrium-aluminium-oxynitride liquid which is necessary for densification. This then forms an intergranular glass on cooling. Syalon 101 is a fully dense ceramic characterized by high strength and toughness.



As a solid solution, the vapour pressure of  $\beta$ -sialon is lower than that of  $\text{Si}_3\text{N}_4$  and as a result the sialon will form more liquid at a lower temperature with  $\text{Y}_2\text{O}_3$ . Sialon is thus more easily densified using normal sintering techniques. Furthermore, it should be noted that the lower vapour pressure of sialon reduces decomposition at high temperatures so that the sialon is thermodynamically more stable than  $\text{Si}_3\text{N}_4$ .



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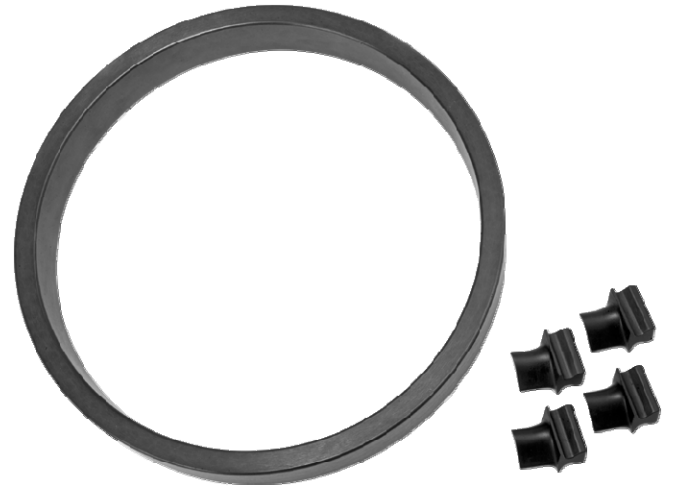
## What are Sialon Ceramics? continued...

### $\alpha$ -Sialon

The second form of  $\text{Si}_3\text{N}_4$  with which sialon is iso-structural is  $\alpha\text{-Si}_3\text{N}_4$ . The stacking structure in  $\alpha\text{-Si}_3\text{N}_4$  is different from  $\beta\text{-Si}_3\text{N}_4$  in that the long 'channels' which run through the  $\beta$  structure are blocked at intervals. This gives rise to a series of interstitial holes. In  $\alpha$ -sialons, Si in the tetrahedral structure is replaced by Al with limited substitution of N by O. Valency requirements are satisfied by modifying cations occupying the interstitial holes. In this way cations of yttrium (Y), calcium (Ca), lithium (Li) and neodymium (Nd) for example can be incorporated into the structure.

International Syalons market an  $\alpha$ -sialon under the trade name **Syalon 050**.  $\alpha$ -sialons are intrinsically hard materials. Hardness can be simplistically related to bond energy density, which for  $\alpha$ -sialons is high, giving extreme hardness. In addition, during sintering and subsequent heat treatment of  $\alpha$ -sialons such as Syalon 050, the intergranular phase is taken up into the structure resulting in a dense,

hard ceramic which is almost free of a grain boundary phase. This results in the material properties being retained at up to 1400°C, with improved oxidation resistance.



### O-Sialon

The final form of sialon, O-sialon, is iso-structural with silicon oxynitride ( $\text{Si}_2\text{N}_2\text{O}$ ). The structure of  $\text{Si}_2\text{N}_2\text{O}$  consists of layers of  $\text{Si}_3\text{N}_4$  rings joined by Si-O-Si bonds. In O-sialon, Al and O replace some Si and N atoms.

International Syalons don't manufacture an O-sialon as, although they have good refractory properties,

they are low in strength and toughness and therefore are not bracketed as advanced ceramics. They are effectively a refractory with no benefits over  $\beta$ -sialon for example, other than cost, although the much superior properties of  $\alpha$ - and  $\beta$ -sialon provide much greater service life, thus offsetting any supposed cost benefits.

### Summary

As explained above, sialons are a diverse family of ceramics covering a wide range of physical properties. International Syalons are continuing to investigate the sialon system in an effort to develop improved properties, such as increasing fracture toughness, thermal conductivity and high temperature strength as well as developing a material with high temperature electrical conductivity. It is anticipated new materials will be introduced over the coming years.

### Technical Support

The successful integration of Syalon ceramics into industrial and engineering systems requires close collaboration between you, the end-user, and us, the material suppliers. Our Technical Specialists are available to discuss your requirements in detail and assist in exploiting the significant advantages which our Syalons have to offer.



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