[+]SIALON CERAMIC MATRIX COMPOSITES

مواد مركبة سيراميكية ذات أساس سايلون

Shaker J. Edrees [*]

Abstract:

The material under investigation is Sialon matrix reinforced with TiN. The Percentage of TiN is changed until maximum density is achieved. TiN is added to improve hardness, fracture toughness and density.

المستخلص :-

في هذه الدراسة يتم تغير نسبة الـــ TiN المضافة إلى الأرضية من Sialon لغرض الحصول على اعلى كثافة ومن ثم تحسين في الخواص الميكانيكية الأخرى . أن الهدف من هذه الإضافة هي لتحسين الصلادة ومتانة الكسر للمادة لغرض ملائمتها للتطبيق المعين

Introduction:

Strength and hardness are major requrrements in engineering materials and these have been recognised as characteristics which give ceramics their unique value for certain engineering material application[1] . The application of ceramic materials, however, is limited by their brittle nature and any improvement in the fracture toughness of these materials would considerably expand their range of applications .

By incorporating a second phase in the structure of a material toughness can be increased[2] .

The particle-reinforced composites with nitrides, carbides and borides of the transition elements (TiN, TiC, TiB2, ZrN) have found some special applications as cutting tools [3] .

A group of ceramics known as " Sialons" has been intensively investigated because of their outstanding properties as high strength refractory material ,since 1976 their use as acutting tools has been explosed and they have been very successful in several application[4,5]

Sialons (Si-Al-O-N) are silicon nitride-based materials with aluminum and oxygen additions[6,7] . Silicon nitried (Si3N4) has useful properties, including high hardness, bend strength better than alumina, and low coefficient of thermal expansion, giving good resistance of thermal shock[8] . It has been tried as a cutting tool material but has not been used industrially partly because it can be produced in high-density form only by hot pressing, so that the cost of accurately shaped tools is very high. Research on sialons has demonstrated that tool inserts can be produced by aprocess similar to that used for cemented carbide [9] .

The sialons ;

In 1972 Jack in England and Oyama in Japan found that silicon in the tetrahedral Framework of Si3N4 may be partially replaced by Al . IF simultaneous replacement of

[+]**Received on 1/9/2002 ,Accepted on 1/3/2003 .**

[*]**Lecturer - Babylon University / Material Eng. College**

Nitrogen by Oxygen occurs. The general term sialon (Silicon aluminum Oxynitride) or β - Sialon has been used to identify this solid solution[8].

The general formula for β - sialon is Si6-z AlzOzN8-z where z is the amount of Si and N replaced by Al and O. [7] .

Studies of the fibraction and properties of sialon-TiN composites are investageted. Sample of 95% to theoretical density are produced in which the fracture toughness increases by 30% in sample containing 30 % TiN.

A small drop of hardness accompanies the increase in fracture toughness but this composite shows considerable promise as a strong, wear resistant material .

Experimental:

The raw materials used in this work are sialon 20l group supplied by cookson, and TiN powder supplied by Goodfello metals. The sialon – TiN mixture was wet mixed using 2-propanol for one hour.

After drying, powder compacts were made by die pressing. The samples were sintered at high temperature in argon gas for different lengths of time at sintering temperatures in the range of (1500-1650 ^{o}C). Weight loss during sintering was minimized by embedding the compacts in a protective powder bed.

The sintering process was characterized by measuring the weight changes of the samples, density, hardness and fracture toughness. Hardness (Hv10) and indentation fracture toughness ($K1c^{idt}$) temperature were determined using Vickers diamon indenter and 10 kg load .

The fracture toughness evaluated by the lawn and fuller method Kc = 0.0515 P/D(3/2) [10] .

Where P = identation force D = is the surface radial crack length

Result and Discussion

Weight change on sintering :-

Typical weight-change behaviour as a function of sintering temperature and time is shown in Fig. 1 in which all the experiments were carried out for one hour period on 30 % TiN-sialon mixture .

The weight change, which is due to SiO gas volatilization as can be seen from Fig.1, increase slightly with temperature. It was also be noticed that at 165oC^{o} time represents an important factor in weight loss hence 5% weight reduction occurred in the sample fired at 1650 C^{o} for 3 hours, while it is only 3.6% for one hour sintering .

This is due to the continous consumbtion of the sialon. The weight loss from the sintered sample increases with temperature .

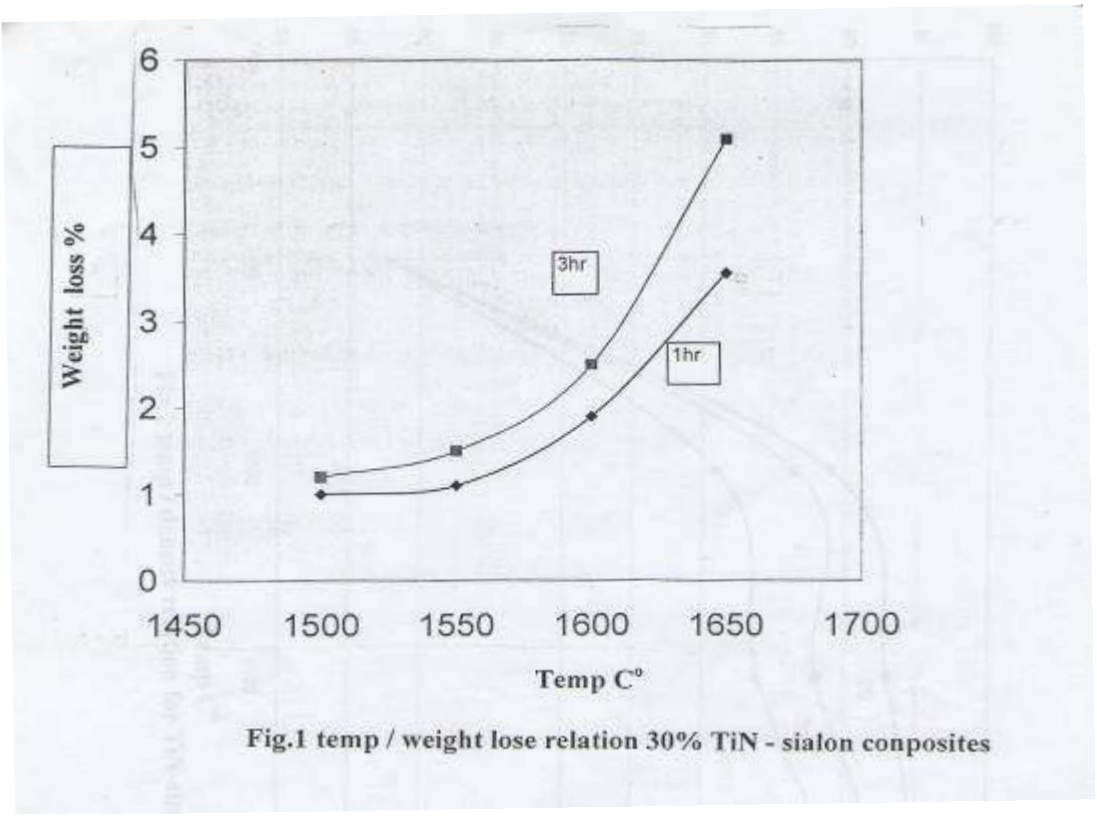

Fig.1 temp / weight lose relation 30% TiN - sialon conposites

Density:

The observed densities vary with sintering temperature for all three mixture (10 %, 20 % and 30 % TiN-sialon composites) .

The density increase with temperature up to 95%, 93% of theoretical density for both mixture 10% and 20% TiN-Sialon resp., and slightly increased up to 1650C^{o} for the third mixture, the miximum density (94% TD) is achieved at 1650C^{o} for one hour sintering time. Fig. 2 shows that the maximum densities and the slops of density temp. curves are similar for both mixture contaning 10 % and 20 % TiN while slop of the third curve is slightly lower.

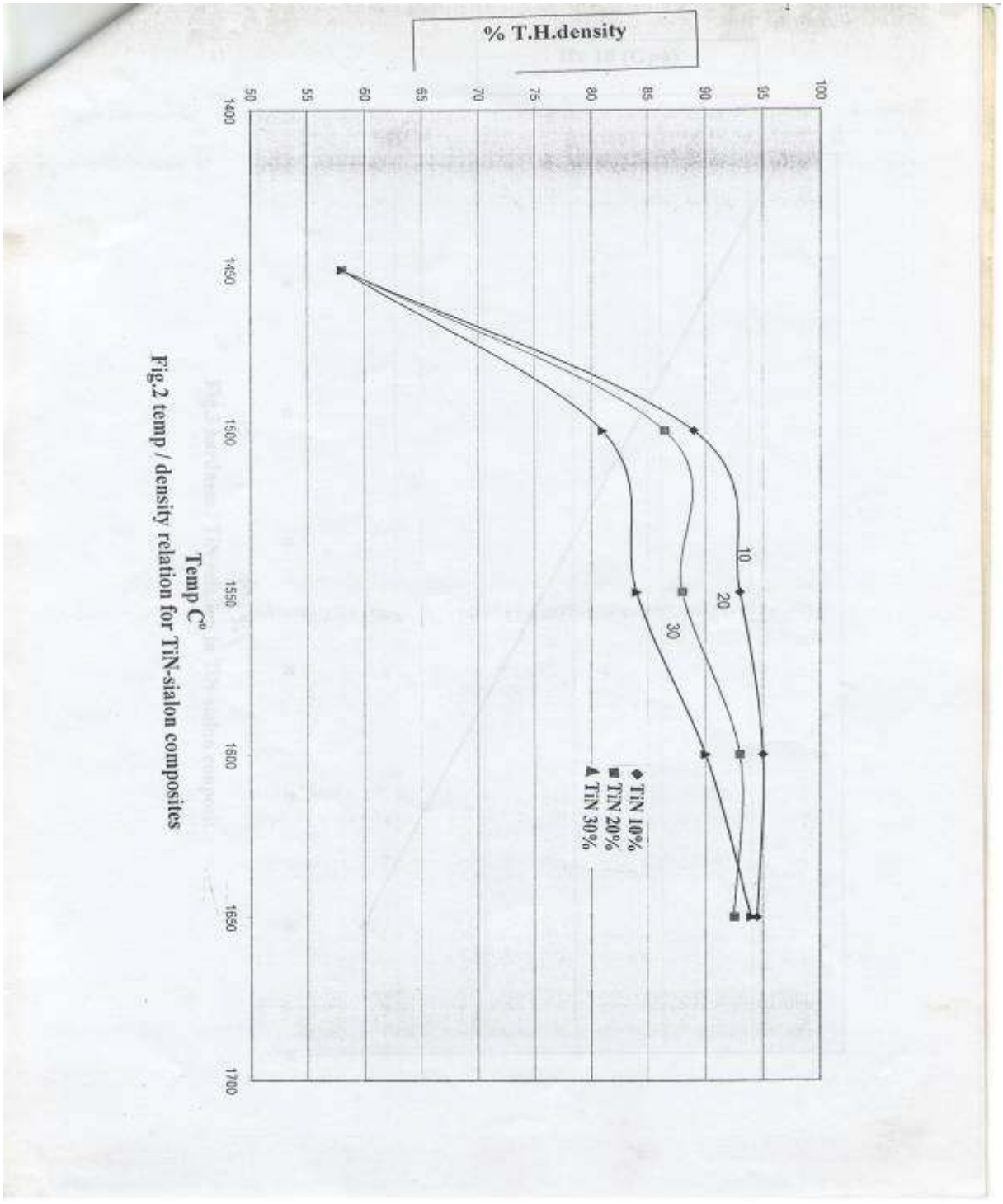

Fig.2 temp / density relation for TiN-sialon composites

Hardness and Fracture toughness :

The hardness and Fracture toughness measured with the indentation method, was evaluated for all mixtures. The aim of this study was to increase the hardness of mixture by dispersion of hard particles but the results show that the hardness always drops with increasing amount of TiN in the mixture.

In the TiN/ sialon system the addition of TiN component to the sialon matrix should result in improvement in hardness at the expense of fracture toughness as TiN is a vary hard and brittle phase and in bulk form is harder than the sialon matrix[2].

The results of the influence of TiN on hardness are given in Fig (3) in which it can be seen that the reduction in hardness occurs with increasing TiN volum fraction in the matrix . Herrman et al . reported that the rate of densification in a (0 – 40%) TiN –sialon composite decrease with increasing volum fraction of TiN [3] .The higher the sintered density the less the amount of porosrty which related to better hardness .

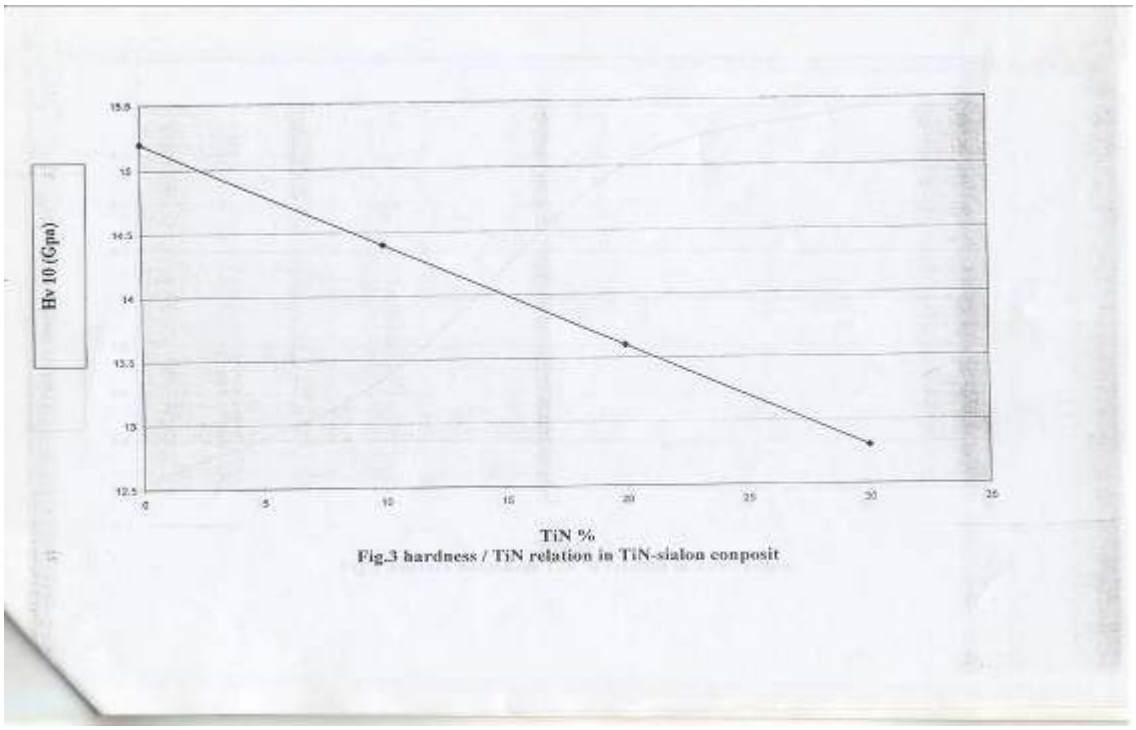

Fig.3 hardness / TiN relation in TiN-sialon composit

The experimental results show that the influence of TiN in the sialon matrix is to improve fracture toughness considerably and a continouse improvement is a chieved with increasing amount of TiN in the structure as presented in Fig (4).

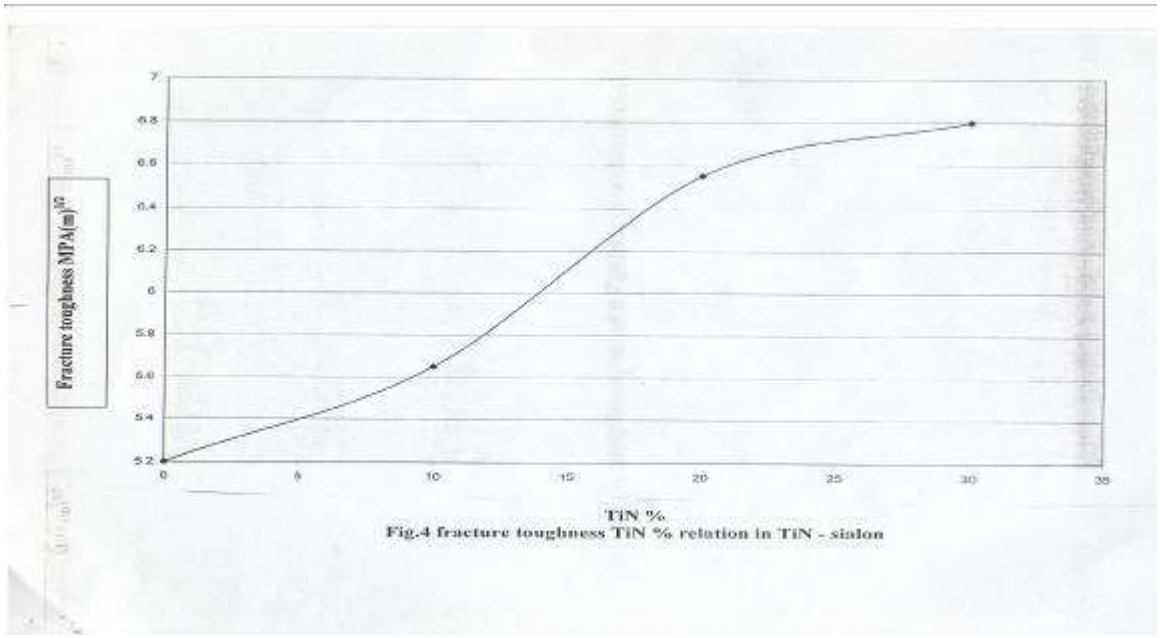

Fig.4 fracture toughness TiN % relation in TiN - sialon

The fracture toughness depends on the way that the crack tip behaves when meets TiN particles ,and as we observed from Fig (5 to 8) the crack length decreas with the increasing of TiNparticles because TiNparticles harder than sialon matrix and dispersion strengthing mechanism is the composites .

Fig (5) optical micrograph of vicker indent on sialon surface.

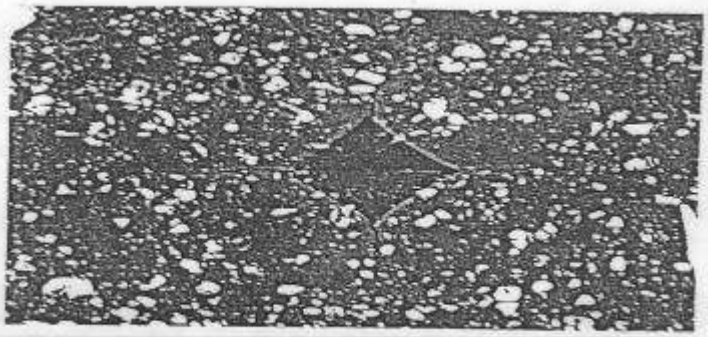

Fig (6) optical micrograph of vicker indent on 10% TiN sialon surface.

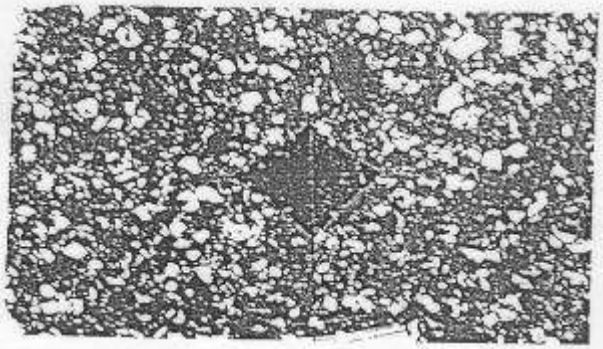

Fig (7) optical micrograph of vicker indent on 20% TiN-sialon surface .

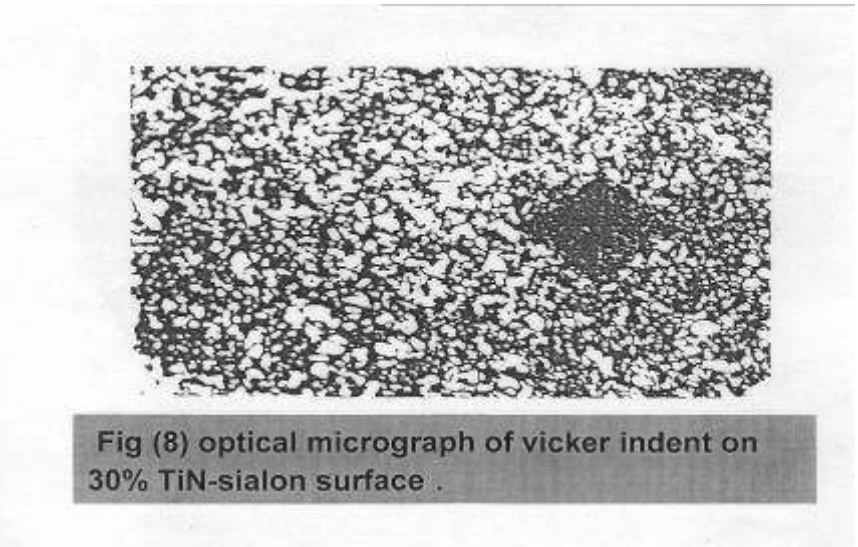

Fig (8) optical micrograph of vicker indent on 30% TiN-sialon surface .

Conclusion

1. The mechanical behaviour of these materials on the mechanism lead to an increase in fracture toughness with a correspoding decrease in hardness.
2. An increased in density is achieved at 1650C^{o} for one hr sintering time.

References :

1- H.J.Edrees ,G.E.holling ," Sialon bondry systems for silicon carbide composites " *British ceramics transactions* VOL. 9-1 ,NO.2-1995 .
2- H.J.Edrees ,A.Hendry " Sintering of silicon nitried based ceramic matrix composites " *imech EC* 4121007,1941 .
3- M.Herramam.B.Balzer,chr.schuber and W.Hermel "densification , microstructure and properties of Si3N4 - Ti(C,N) composites" :*J.European ceramic.soc*,1993(287-296) .
4- C.C.Sorrell and E.R.McCartney "Engineering nitrogen ceramics": *Materials Forum* Vol .9.No.3 -1986 .
5- E.M.Trent "*Metal cutting*" *second Edition ,Butter worth* Ltd.-1984 .
6- P.Popper "Engineering ceramics for use at high temperature " *nternational sympo. On ceramics*, 29-30 Nov. ,India ,1982.
7- K.H.Jack " The crystal chemistry of the sialon ,and related Nitrogen ceramii\cs" , 1989 .
8- P.Greil "Opportunities and limits in Eng. Ceramics" *powder Metallurgy Internat* VOL.21 ,NO.2,1989 .
9- E.D. Whitiney "modern ceramic cutting tool materials" *powder Metallurgy Internat* .,VOL 15 ,NO.4,1983 .
10-C.B.Ponton ,R.D.Rawlings"Vickers indentation Fracture toughness part 1″ *Materials science and technology* VOL.5 ,sept. ,1989 .
11-A. Hendry ,H.J.Edress "Shrinkage and densification of particulate reinforced ceramic matrix composites " *British ceramic transaction* VOL.98 NO.1 1999