Effect of Various Binders on Silicon Carbide Foam Prepared by Replication Technique

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***Abstract*— Ceramic foams are open -celled structures of an interconnected lattice of ceramic bond. Macroporous Silicon carbide ceramic foams (SiC) can operate at high temperatures and can be used for applications such as filtration for gas and water, absorption, catalyst supports, concentrated solar power, thermoelectric conversion, etc. As the application domains for these materials vary widely, the ultimate properties of the foam posed by the specific use are also diverse. As a consequence diverse routes to fabricate macroporous SiC foam with porosity ranging from 9% to 95% have been developed. In this project, effect of various binders on preparation of SiC foam by polymeric sponge replication method is studied by impregnating polyurethane foam with mixture of ceramic slurries, various binders, and additives. The morphological study of scrupulous sample is performed using scanning electron microscopy (SEM).**

Keywords*— Silicon carbide foam, Binders, Replica method

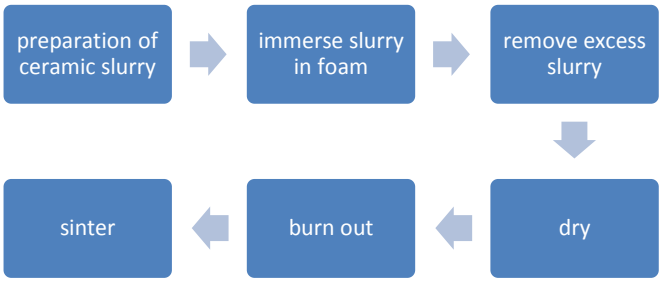
1. INTRODUCTION

Foam is a material characterized by a three dimensional interconnecting network of struts generally having open connectivity to all pores. Among the ceramic foams, Silicon carbide (SiC) foams are characterized by high strength at high temperature, good thermal shock resistance, and excellent oxidation resistance. It is widely used as catalyst carriers, high temperature insulation materials, and filters for hot gases and molten metals [1]. Depending on the application-property requirement, various techniques are developed to prepare SiC foams. Some of the widely followed methods for production of SiC foams are: Replication, Freeze casting, Template conversion, Hollow beads, Bubble generation, and Chemical infiltration vapor techniques. SiC foams are categorized in following two types: **1.** SiC foams produced from commercial SiC powder and polyurethane sponge by sintering after a coating process, and **2.** SiC foam prepared by filtration of liquid or gas silicon into various carbon templates (also known as Template conversion) [3].

It has been widely reported that powder sintering needs higher processing temperature and pressure than template conversion in order to realize densification and strengthening of SiC foams. This is due to the difference in sintering mechanism between two processes. Therefore, template conversion process attracted more attention because of realizable structure- design and it is relatively easy to produce various templates.

The replication of polymer foams is one of the first manufacturing techniques developed for producing ceramics foams. The Replica technique was used to fabricate high porous ceramic foam for liquid metal infiltration using polyurethane [4].

Various steps in replication technique are shown below.



The slurry consists of ceramic powder with the appropriate addition of solvent, dispersant, polymeric binder and other additives, e.g. plasticizer or surface-active agents [2]. SiC powder, binder and water of desired amount blended together to prepare ceramic slurry. The slurry should have optimum viscosity to properly coat the polyurethane (PU) sponge. If the viscosity of slurry is too high then it may not flow and result in partial coating of the PU sponge and in contrast if the viscosity is too low then slurry won't adhere to the PU sponge. Therefore, it is very important that the viscosity of the slurry is properly controlled during the process. After the slurry is prepared, the PU sponge is dipped multiple times and excess slurry is removed after each dipping process. This process is continued till the entire sponge is adequately coated with the slurry. The coated sponge is subsequently dried and sintered to desired strength. A replica of the sponge is thus obtained which has the same number and size of pores as in the sponge. This replica is known as the PU foam, which is further used in many applications. The weight of the foam before drying and sintering is noted for record.

2. EXPERIMENTS

2.1 Process for production of SiC foam by replica technique

Various steps followed to produce SiC foam are described below:

1. Raw materials used for the production for SiC foam are: polyurethane foam; SiC powder, different binders such as - sodium silicate, fumed silica, colloidal silica, and starch.
2. Slurry was prepared by adding water to SiC powder and Binders. Binder makes the slurry solvus and helps the silicon carbide particles to bind properly and form slurry. Different compositions of slurry are shown in Table 1.
3. PU foam was cut in suitable dimension and immersed into the slurry. Then it was taken out and is rolled to squeeze out the excess of the slurry. The same process is repeated for several times so that foam absorbs the entire slurry and no pores are blocked.
4. Squeeze foam was air drying for around 10-15 minutes. Then the foam was oven dried at 100°C – 110°C for 1 hr.
5. Dried foam was sintered at 900°C to burn out the polymeric foam from the inner part of the ceramic structure as well as to remove any organic binder from the ceramic slurry.
6. Prepared SiC foam was characterized by SEM to study the morphology and interconnectivity of porous.

3. RESULTS AND DISCUSSION

Table-1 shows an overview of various samples prepared by using different binders and result of visual observation. Two types of binders are used in the experiments 1. Inorganic Binders such as sodium silicate, colloidal silica, fumed silica. 2. Organic binders namely starch. The main constituent is SiC powder. Other ingredients such as organic and/or inorganic binders are added in different proportion as shown in the table-1. Water is used as a vehicle for making the slurry. The ingredients are mainly additives which facilitated bonding at elevated temperatures. Thus, initially the PU foams were immerged in the slurry followed by air drying and oven drying and then sintering at temperature of 9oo °C for developing the high temperature bond strength on evaporation of PU foam. Every batch consists of an average of three representative samples.

To improve the compressive strength and bonding strength we used other different inorganic/organic binders with the sodium silicate, as shown in table-1.

4. : CONCLUSIONS

1. SiC foams were successfully produced using polymeric foam replication method.
2. Sodium silicate is the basic constituent which is used as a binder and SiC is the matrix phase which has produced a high temperature viscous liquid on firing followed by in-situ solidification on cooling yielding foam structure with adequate strength and porosity.
3. This phenomenon is mainly dependent on the proportion of constituent present in the slurry and the firing temperature.
4. From the results it is evident that the firing temperature of 900 °C is appropriate. The firing event remains constant for all samples.
5. The constituent of the slurry namely SiC = 8 gm, Sodium Silicate = 6 gm & Water is appropriate and can be used for commercialisation of the product.

5. REFERENCES

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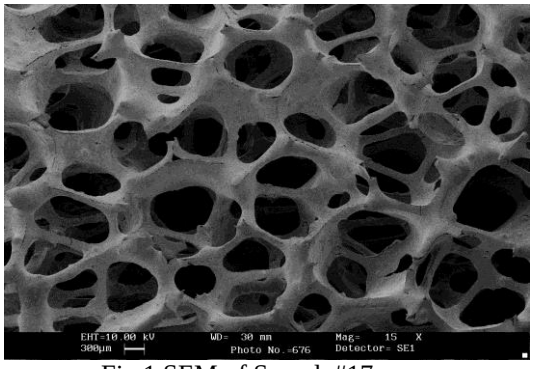

Fig.1 SEM of Sample#17

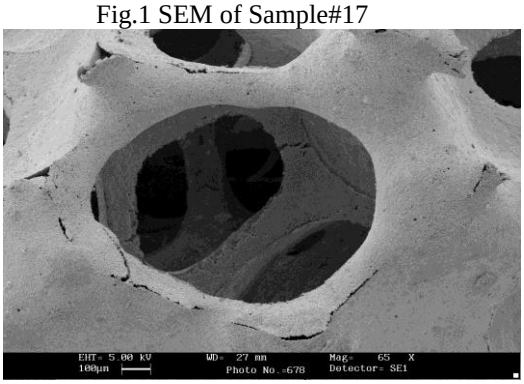

Fig.2 Pore Size image

Table 1: Effect of different binders on SiC foam

Representative Sample	Composition Of Slurry	Drying & Sintering Process	Observation	Remarks
Batch 1: 	SiC:5gm Sodium Silicate : 5ml Water	Samples were air dried then kept in oven at 60°C for 1hr. Sintered at 900°C.	Formed foam structure, But less strength. Good porosity	Both SiC and Sodium silicate when heated to high temperature SiC powder will dissolve in hot sodium silicate. They will produce a high temperature viscous mass which on cooling to room temperature will produce a strong, rigid porous structure. In the present case the proportion of the constituents seem to be inadequate and therefore poor strength but good porosity.
Batch 2: 	SiC: 5gm Sodium Silicate : 5ml Starch:7gm water	Samples were air dried then kept in oven at 60°C for 1hr. Sintered at 900°C.	Rigid, no pores, and fermented structure.	Starch as organic binder has not contributed anything on the bonding mechanism at elevated temperature and thus the structure is weak, brittle and non porous.
Batch 3: 	SiC:5 gm Sodium Silicate : 5 ml Colloidal silica: 5.5 ml Water	Drying in oven for 100c for 1 hr. Sintered at 900c in furnace	Extremely brittle and disintegrated into powder.	Colloidal silica together with sodium silicate and SiC is expected to yield better products after sintering. However it has not happened so. This may be attributed to the fact that the proportions used for forming the high temperature phase and its stability at room temperature is far from adequate.
Batch 4: 	SiC:17gm Sodium Silicate : 5.5gm Fume silica: 7gm Water	. Drying in oven for 100c for 1 hr. Sintered at around 900c in furnace	Low strength and hardness , poor structure & porosity	Fume silica is another bonding agent together with sodium silicate and SiC. In this composition the undissolved and excess SiC has resulted in blocking of the pores during the solidification process. Fume silica also seem to have not contributed in the bond formation at high temperature.
	SiC = 8 gm Sodium Silicate = 6 gm Water	The samples were dried in oven at 100c for 2 hrs Sintered at around 900c in furnace	Formed foam structure, good strength and hardness. Good structure	In comparison with the sample batch-1, it is apparent that the sample from batch-5 has shown best result in terms strength, porosity and structure. The composition selected for this sample on trial and error basis seems to be the perfect one. This has been demonstrated in the SEM photographs. The inter connectivity of the pores need to be studied further.