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EVALUATION OF MICROSTRUCTURE AND HARDNESS OF FUSED ZIRCONIA-ALUMINA FOR ABRASIVE APPLICATIONS

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ABSTRACT

The experiments using available indigenous raw materials have resulted in fixing conditions for the preparation of zirconia-alumina abrasive materials. SEM photographs of typical samples of zirconia-alumina have been taken and the hardness of the samples determined with a Rockwell hardness tester. The microstructure enables evaluation of the grain shape which in turn controls the abrasive operation to be used viz cutting, grinding or lapping. The hardness values indicate the toughness of the grain.

Key Words: Fused ZrO_2 — Al_2O_3, Microstructure, hardness, abrasives.

INTRODUCTION

Fused zirconia-alumina is a super-abrasive material whose development dates back to 1960s [1]. It is particularly useful for high pressure, large stock removal grinding operations in the industry. A comparison with fused alumina indicates that the fused zirconia-alumina stays sharp for a much longer time and removes greater stock of metal. Fusion-cast zirconia-alumina ceramics form excellent abrasion-resistant grains suitable for snagging steel and other metal ingots [2]. Its application as lining in glass melting furnaces results in the production of high quality glass as it is insoluble in molten glass [4].

The zirconia-alumina forms an eutectic system at 1900°C [3] (Fig. 1).

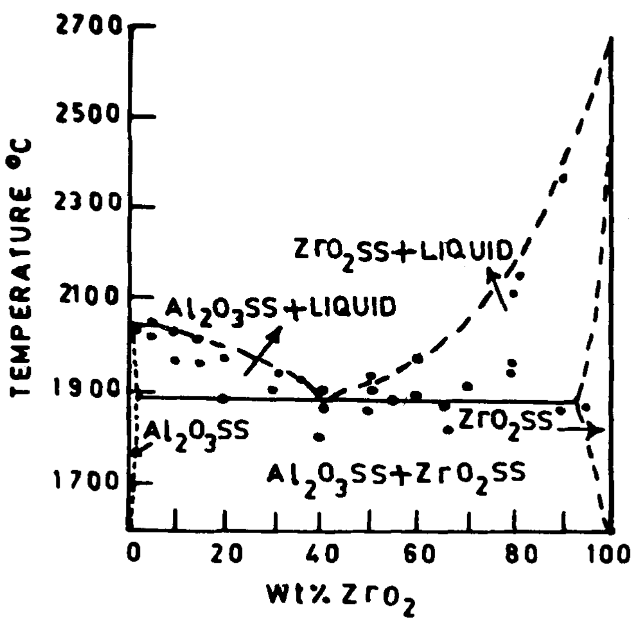


Fig. 1: Phase diagram of ZrO_2-Al_2O_3 system [4]

There is limited solid solution at high temperatures. After fusion casting, during the cooling period in the mould, pure alumina crystallises in a columnar structure and due to shrinkage during solidification, voids develop between columnar crystals which become weak and have poor resistance to thermal shock. However, the structure becomes more equiaxial and stronger when zirconia is added to alumina.

It is stated that the compositions which fall between α-alumina and the eutectic contain primary crystals of alumina surrounded by the eutectic composition. The eutectic composition comprises mainly of alumina with inclusions of rod-like zirconia crystals. The eutectic grains are observed to grow along a three-fold symmetry axis of the α-alumina.

In the case of compositions which fall between the eutectic and pure zirconia, the latter is surrounded by the eutectic phases. With high zirconia content (above 60%) in the system, the primary crystals of zirconia become equigranular in shape. However, when the zirconia content is less than 60%, it tends to crystallize in a dendritic and needle-like manner on melting.

EXPERIMENTAL

Using zirconia and alumina (both C.P.grade) in the charges along with small quantities of wood charcoal, experiments were conducted in the 60 kVA single phase arc furnace. The products were allowed to cool in the furnace and then removed for examination. Four typical samples with compositions of zirconia in the range 30% to 90% and that of alumina 10% to 70% were prepared. Scanning electron microscope photographs of the surfaces of the samples were taken and the hardness values determined using a Rockwell Hardness Tester.

RESULTS AND DISCUSSION

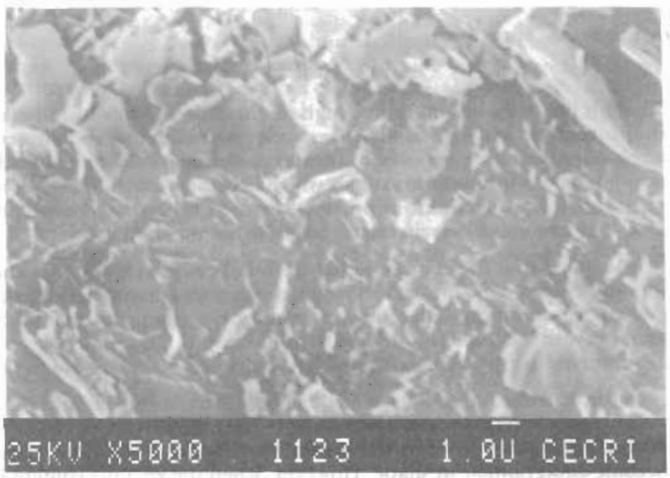
The results of the experiments are given in Table I and the SEM photographs in Fig. 2 (a to d)

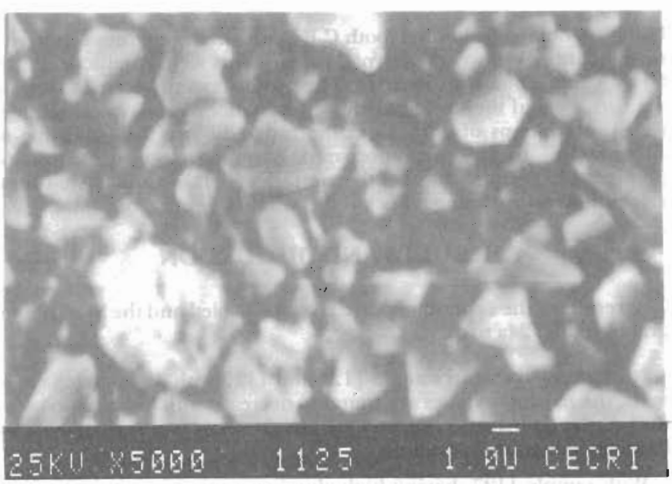
It is observed that in sample 1123 and 1125 with high zirconia contents, the hardness values are found to decrease with less alumina content. As the grains are equigranular in shape, these types are suitable for loose grain lapping operations.

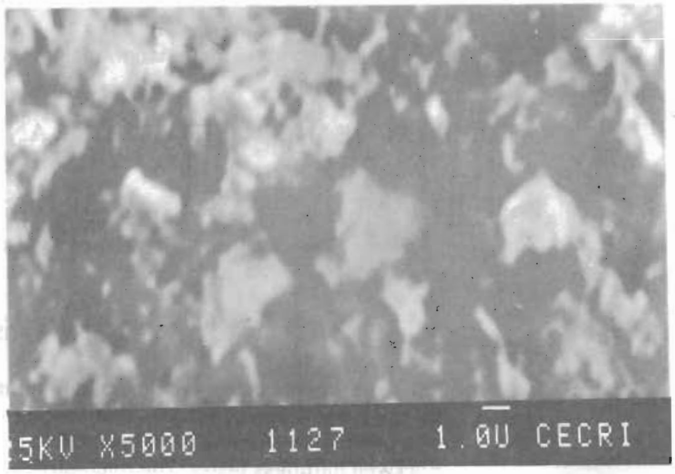
With sample 1127, having high alumina content in eutectic matrix, the grains are rough and not so sharp but they would possess high

Table 1: Microstructure and hardness of fused zirconia-alumina samples

S. No.	Sample number	Composition of product		Microstructure (magnification 5000 ×)	Hardness, RA (scale A - Rockwell Diamond Indentor)
		% ZrO_2	% Al_2O_3		
1	1123	76	24	Equigranular and flaky crystals in eutectic matrix. A few are sharp.	68.5
2	1125	90	10	Same as above except that crystals have blended corners.	44.7
3	1127	30	70	Primary crystals of alumina in eutectic matrix (irregular in shape). A few crystals are sharp.	73.2
4	1129	50	50	Primary crystals of zirconia (needle shape) in eutectic matrix.	78.5







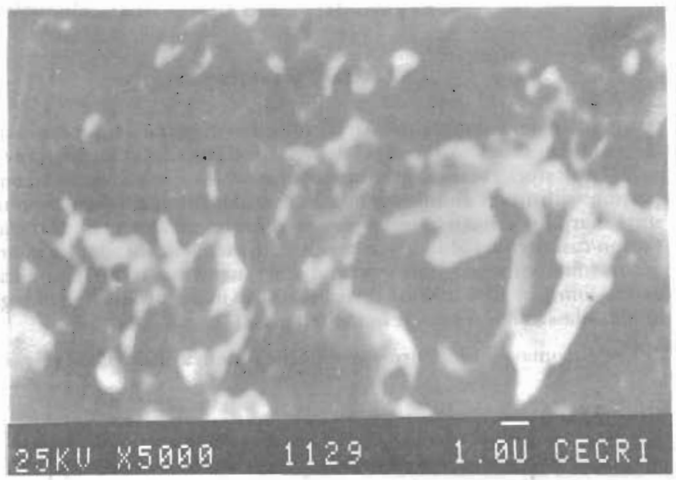


Fig. 2: SEM photographs of fused zircomia-alumina
(a) 76% ZrO_2 and 24% Al_2O_3
(b) 90% ZrO_2 and 10% Al_2O_3
(c) 30% ZrO_2 and 70% Al_2O_3
(d) 50% ZrO_2 and 50% Al_2O_3

mechanical strength in view of the increase in hardness values. This type can be used for heavy duty grinding of billets and slabs in steel mills as the body strength is sufficient to resist fracture until the points become dull and then break to prevent a new edge. A 25% ZrO_2 and 75% Al_2O_3 alloy has been used for the above operation by the U.S. firm which developed this abrasive material.

In the SEM photograph taken with sample 1129, sharp grains are obtained and these are very near to the eutectic. When such grains are used for cutting stock, these tend to fracture to a large extent and thereby provide new cutting edges. Besides, the hardness value obtained with this sample is the highest among all the samples. This type is very useful for cutting operations. A 40% ZrO_2 and 60% Al_2O_3 alloy developed by the U.S. firm has been found to be applicable for light duty such as cutting-off, portable grinding and coated abrasive operations.

The alumina content is found to have a distinctive effect on the hardness of the samples. If its percentage is high above the eutectic, then the hardness is in the increasing order and if it is lower than the eutectic, its values come down.

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