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REFRACTORY COATINGS ON GRAPHITE ELECTRODES USING FLAME AND PLASMA SPRAY TECHNIQUES

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Studies have been undertaken to protect graphite electrodes thereby minimising their consumption in the arc furnaces. In this paper, results of the experiments conducted to provide hard and adherent coatings employing 4-5 micron size spherical alumina - titania powder are presented. Flame and plasma spray methods were employed for evaluating the coatings performance. The merit of the coatings is discussed from a comparison of the SEM photographs of the coated specimen as such and of the high temperature tested specimen.

Key words: Refractory coating, graphite electrode, flame spray, plasma spray, SEM studies

INTRODUCTION

Largest tonnages of graphite electrodes are used in the arc furnaces employed for the production of electrothermal products such as calcium carbide, pig iron and steel. These electrodes are consumed during the furnace operation and any reduction in the consumption of these electrodes will extend their useful life. Several coating techniques have been developed for coating hard adherent ceramic refractory compounds over graphite electrodes. The work carried out at CECRI initially employed dip coating and electroplating methods along with SEM studies [1,2]. In the current investigations, flame and plasma spray techniques are used. The merits and demerits of the above mentioned techniques were reported elsewhere [3]. Flame spraying technique differs from plasma spraying, in that combustible gases are used in part to generate heat for melting the ceramic powders while a high intensity electric arc ionizes the spraying gas to create ultra-high temperature obtained in the plasma spray system. This paper compares the Scanning Electron Photomicrographs of alumina-titania coating over graphite electrodes using flame and plasma spray techniques.

EXPERIMENTAL

One inch dia. graphite electrodes with sand blasted surface was made for flame spray system and no surface preparation for plasma coating. The powder used for coating contained aluminium oxide 60% and titanium oxide 40% with particle size in the range 4-5 microns and the shape truly spherical. Powder jet 85 - for flame spray system and plamatron plasma spray system of Model 3600-40D were used. In flame spray system acetylene-oxygen gaseous mixtures were employed for generating heat with provision for oxygen gas to carry powders. Argon gas was used both for plasma forming gas and carrying powders in the plasma system.

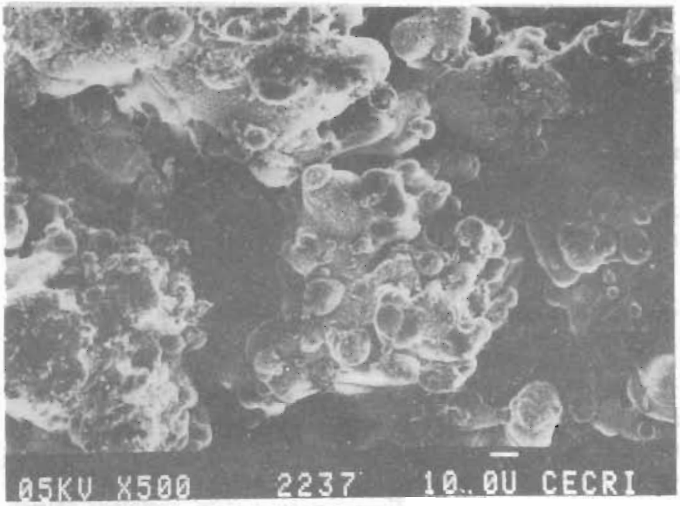
RESULTS AND DISCUSSION

Table I gives the characteristics of flame spray coating. Fig. 1 (a-c) (2237, 2239 and 2241) show the coatings of alumina-titania over graphite electrodes at room temperature, at 1273K in reducing atmosphere and at arc temperatures. The flame temperature of acetylene-oxygen gaseous mixture is limited to < 3273K and the burning process which produces CO_2 and H_2O is an endothermic reaction of dissociations, limiting further the increase of the temperature [4]. So high melting point materials cannot be sprayed by this technique. The structure of the sprayed material seems to be crystalline. The loose "heaped structure" formed in Figs. 1 (a & b) are due to great nozzle distance between the substrate and the gun. This gives rise to cooler particles which have lower velocity. At the arc temperature due to poor adhesion of the coating to the substrate it fails exposing graphite flakes as in Fig. 1(c). This indicates the limitations of flame spray techniques.

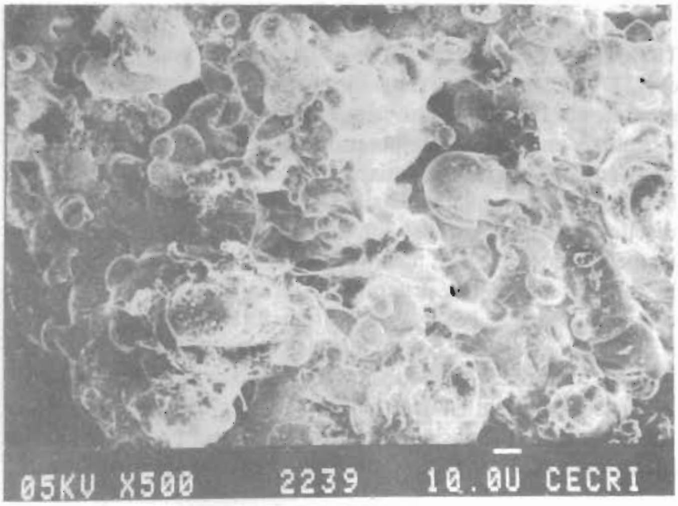
TABLE-I: Characteristics of flame spray coating

S.No.	SEM photo-micrograph No.	Magnification (X)	Type of coating	Characteristics	Remarks
1	2237	500	Al_2O_3 -TiO_2 as such	Cluster of particles	Adhesion to the substrate is poor
2	2239	500	Al_2O_3 - TiO_2 but heated to 1273K reducing atmosphere	-do-	-do-
3	2241	500	Al_2O_3 - TiO but heated arc temp.	Graphite flakes can be seen	Failure of the coating noted

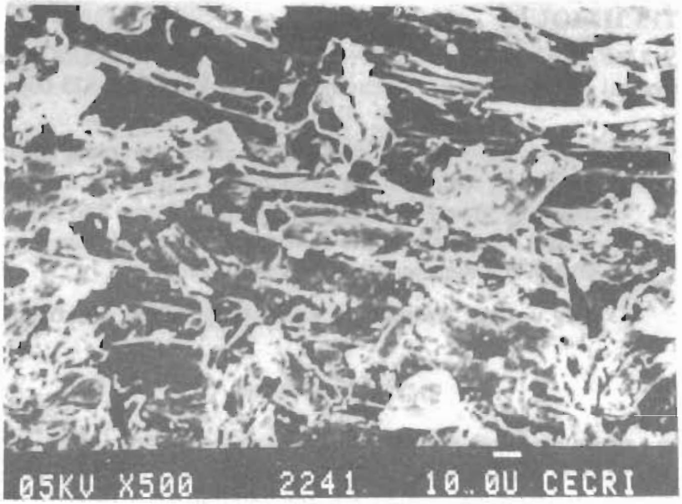
Fig.1: SEM Photomicrographs for



1 (a) Flame spray as such

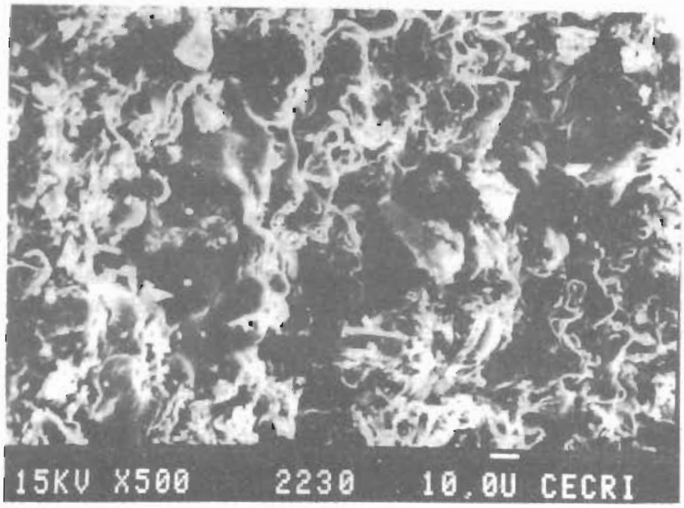


1 (b) Flames spray reducing at 1273K



1 (c) Flame spray arc temperature

Fig.2: SEM photomicrographs for

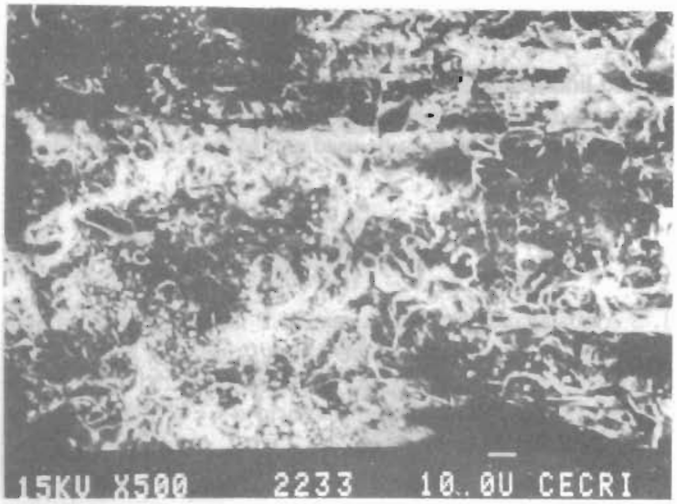


2 (a) Plasma spray as such

TABLE-II: Characteristics of plasma coating

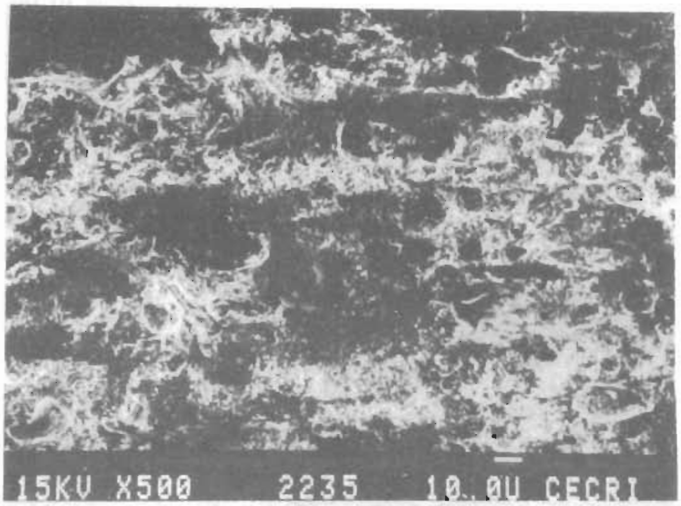
Sl.No.	SEM photo-micrograph No.	Magnification (X)	Type of coating	Characteristics	Remarks
1	2230	500	Al_2O_3-TiO_2	Fusion of the particles over the substrate noted	Good coverage longitudinal section certain amt. of voids
2	2233	500	Al_2O_3 - TiO_2 but heated to 1273K reducing atmosphere	Reorientation & fusion of the particles observed	Full coverage is there
3	2235	500	Al_2O_3-TiO_2 but heated to arc temp	Full coverage of the coating obtained	Withstood arc temp

The characteristics of plasma spray coating are given in Table II. The photomicrograph of Fig. 2 (a) (2230) shows that the coating of alumina-titania over graphite electrode indicates the fusion of the particles over the substrate at room temperature when plasma spray technique was used. Normally molten particles striking a



2. (b) Plasma spray reducing atmosphere

smooth surface undergo severe deformation and flow radially outward from point to point [5]. This depends upon the viscosity, the specific heat, the thermal conductivity of the molten coating material and strongly on the thermal conductivity of the substrate since this determines the flow before solidification [6]. As the viscosity of the droplet is low and the substrate has high conductivity the coating formed is a dense one, porosity in this case is lower than that of the flame spraying method [7].



2. (c) Plasma spray arc temperature

The Fig. 2 (b) (2233) shows (the same coating and techniques similar to previous one) the photomicrographs of the sample heated to 1273K under reducing atmosphere. Here the coverage of the inctpient fusion of the individual particles over the substrate is noted. During spraying tensile stresses are set up by the contraction of individual particles as they are deposited on the work piece. Momentarily the molten particles are in intimate contact with cold solid particles of the substrate; they contract and as the substrate cools, an accumulation of tensile forces results in decrease of adhesion of the coating [8]. During heating there will be relaxation and reorientation of the stresses and diffusion of the particles. In the photomicrographs the cluster and incipient fusion of the particles are seen.

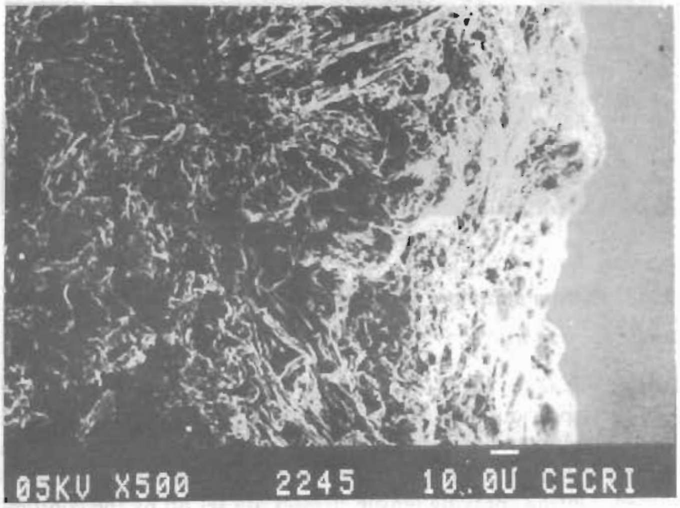
TABLE III: SEM studies of cross section of plasma and flame spray coatings

Sl.No.	SEM photo-micrograph No.	Magnification (X)	Type of coating	Characteristics	Remarks
1	2245	1000	Al_2O_3-TiO_2 coating (plasma) spray	Coating, interphase and substrate can be seen	Good adhesion
2	2244	500	Al_2O_3-TiO_2 (Flame spray)	Coating & substrate can be seen with no interphase	Penetration of the coating into the substrate was not observed

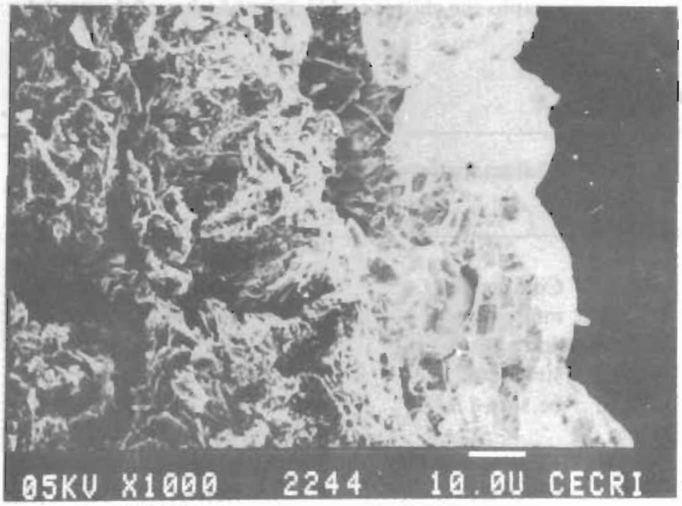
Fig. 2 (c) shows the photomicrograph of the plasma coating at arc temperature. The coverage of the coating is good with minimum porosity. It indicates that the adhesion of the coating to the substrate is very good. Since the melting of alumina-titania is very high the coating withstood the arc temperature.

Table III shows the cross section studies of flame and plasma spray coatings of SEM.

Fig.3: SEM Photomicrographs for



3. (a) Flame thickness



3. (b) Plasma coating thickness

In Fig.3 (a) non-penetration of alumina-titania layer into the graphite substrate is observed whereas penetration is noted in Fig.3 (b) which is due to very high temperature of the order of 15273 - 20273K and high velocity of plasma gas. But the temperature involved in flame spray technique is low not exceeding 2773K. These air sprayed deposits give rise to low bonding and cohesive strength.

CONCLUSION

Due to limitations in the attainment of high temperature in the acetylene- oxygen flame spray techniques ceramics having melting point above 2273K cannot be used and so one has to use plasma spray techniques.

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