dc Resistivity behaviour in fly-ash

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The fly-ash (FA) sample has been collected from a 840 MW thermal power station, Raichur (Karnataka), with a daily FA production of 7000 tons. From the available elemental data analysis, further investigations on the electrical resistivity behaviour of circularly shaped disc of FA have been carried out in the temperature range 100-600 °C. It has been observed that resistivity is gradually decreasing with the increase of temperature. The electrical conductivity and activation energies have been estimated. The possible conductivity mechanism is discussed.

1 Introduction

Fly-ash (FA) is an inexpensive resource material. Basically, FA is a coal product, generated from coal-fired thermal power stations. It is grey in colour and alkaline in nature with pH ranging from 9 to 9.9. About 70% of India's annual coal production is used in about 70 power-generating plants and produce 60 million tons of FA per year. It is likely that it may cross over 90 to 140 million tons during 2001 to 2010 AD$^2$.

Disposal of FA is one of today's burning problems and has been considered as a serious operational constraint and an environmental health hazard. Production of 1 MW electricity requires about one acre of land for the disposal of fly-ash$^1$. On the other hand, there were many experimental analysis on FA to undertake its basic compositional, physical and chemical properties for technical studies and applications$^{2,4}$. Sampathkumar et al.$^6$ studied the synthesis of alpha-corderite (indialite). However, there are very a few reports on investigations on conductivity of fly-ash pellets. Hence, it is interesting to understand the electrical conductivity and feasibility study of fly-ash pellet as a temperature sensor.

2 Experimental Details

A fine, fresh, clean and pure fly-ash powder was collected from the Raichur Thermal Power Station, Raichur, Karnataka. The size of its particles ranges between 5 to 120 µm. It is abrasive and refractory in nature. Chemically, the fly-ash is silica to an extent of 55 to 70 % followed by alumina 10 to 18 % and iron oxide 6 to 20 %, lime magnesia and alkalis vary between 1 to 5 % each. It was reported that fly-ash generally contains elements like, Cu, Ag, Pb, Cd, Fe, Mn, Ti, Na, Cl, Mo, S, P and Zn in different concentrations depending upon the type of coal used$^2$.

The fine powder of fly-ash was shaped to compacted in a cylindrical (10 mm dia × 5 mm thick) pellet. It is heated again to have a hard solid material. This is used for the measurement of dc resistivity using two-probe method. The dc resistivity studies were performed in the temperature range 373-873 K. The arrenhienous relation is given by:

\[ \sigma = \sigma_0 \exp \left(-\frac{E_a}{kT}\right) \]

where \( \sigma \) is conductivity, \( \sigma_0 \) is pre-exponential factor, \( E_a \) is the activation energy and \( k \) is the Boltzman's constant. The plot of ln (\( \sigma T \)) versus 1000/T gives linear graph, the slope of which helps in extraction of the activation energy. The activation energy is the energy required to enable an ion to hop from one vacant site to another.

3 Results and Discussions

A typical plot of resistivity behaviour as a function of temperature is shown in Fig. 1. It is seen from Fig. 1 that, dc resistivity monotonically decreases with the increase of temperature, thus showing a semi-conducting phenomenon. The drop of resistivity is divided into three different regions.

A region before $R^1$ is undefined because certain minimum temperature is required to establish good thermal contact. Once it is achieved, the resistivity almost remains constant up to temperature 693 K. This may be due to insufficient thermal energy to excite the charge carriers. But, after temperature 693 K, in the $R^2$ region there is a sudden drop in resistivity. The decrease in resistivity may be due to clustering of number of different ions occupying different positions, which effectively lower the concentration of stable bonds. Thus, the conduction is due to a hopping process. This is observed up to
temperature 813 K. In the R"¹ region, again, the resistivity is trying to stabilize itself.

The conductivity/resistivity studies on the pellets of fly-ash reveal, ion-hopping type conduction mechanism. The conductivity is of the order of that in usual semiconductors. The Arrhenius plot (Fig. 2) reveals two regions. In lower temperature region (303-613 K), the average activation energy is 0.12 eV, while in higher temperature region (613-873 K), it is 3.2 eV. In the temperature region (303-693 K) the fly-ash is in small particulate distribution and ion-hopping is relatively easy resulting in smaller activation energy. At temperature 713 K, there is a phase transition as seen from Fig. 2. Above 713 K, the fly ash particles fuse to give larger grains which impede the ion movement, resulting in higher activation energy. This material could be used as a temperature sensor when operated in one of the linear portions of the Arrhenious plot.

4 Conclusion

Fly-ash is a waste material in thermal power stations. It is a big hazard for agriculture and vegetation in the vicinity of thermal power stations. Disposal of fly-ash itself is a big industrial problem. This paper investigates electrical conductivity of pellets of fly-ash in a wide range of temperature and indicates possible application of fly-ash-pellet as a temperature sensor.

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References