Summary

Modern electrical switching devices are characterized by small dimensions, higher reliability and long life. These depend on the configuration of electrical contact, in particular on choice of contact material. Prior to 1930's, development of contact materials for arcing switch devices concentrated mainly on silver alloys and silver-refractory composites produced via the powder metallurgy method. In the late1930's, Hansel and his associates produced their first Ag CdO contacts by press-sinter-repress route. Since then, the silver-cadmium oxide has been the most important contact material for low to medium power arcing contacts i.e for contacts switching a few amperes to 1000 amperes at voltages upto 1000 V. AgCdO's wide-spread use as a contact material has been attributed to its excellent resistance to arc erosion, low contact resistance and good antiwelding properties. However, the fact that the vaporization of cadmium oxide during switching could be detrimental to workers' health, its use in contact materials has been banned by health organizations such as OSHA,EPA and ACGIH in some parts of the world. As a result of this, various replacement candidates already developed or under development are Ag SnO_2, Ag NiO, Ag ZnO, Ag CuO, Ag-SnO_2 -In_2O_3, Ag-SnO_2 -WO_3 etc.The development of new contact materials has been marked by two primary objectives :

- saving of precious metal by increasing the erosion resistance
- avoidance of toxic material components

Operating conditions under which the electrical contacts function differ so widely that no single existing material is universally applicable. An ideal material would have the electrical conductivity of silver, the tarnish resistance of gold, the refractoriness of tungsten, the abrasion resistance of tungsten carbide and coefficient of friction of graphite . Since no single system can cater to all these, selection is sometimes simplified

by the overriding importance of one parameter, and in most cases a compromise solution is sought. Ag-MeO composite systems may be looked upon as an outcome of this selection criteria.

The physical, metallurgical and electrical properties of such composite contact materials are mainly governed by the powder processing technique employed and in turn by the homogeneity of mixing between the silver and metal oxide particles. Consolidation of mixed powders is a well established technique to make Ag-MeO composite contact materials. However, one short-coming of most commonly used mixing methods (such as blending, ball-milling etc.) is that the submicron oxide particles tend to agglomerate during mixing. Eventually, the oxide particles exist in the silver matrix in the form of accumulations of fine crystals rather than in the form of single crystals ; adversely affecting the contact performance. As a result of this a variety of alternative powder processing routes such as coprecipitation, internal oxidation, freeze-drying, electroless coating, spray-roasting etc. are being used or under development.

The present investigation was concerned with examining the feasibility of replacing CdO by non-toxic ZnO in Ag-MeO type composite contacts. The work consisted of preparation of Ag-ZnO and Ag-CdO powders, followed by their consolidation into high density compacts by conventional PM techniques.Both Ag-CdO and Ag-ZnO powders synthesized by various processing routes have been characterized in detail and the final hot-pressed compacts have been evaluated for physical, metallurgical and electrical contact properties. Attempts are made to correlate the structure and properties for powders and final consolidated compacts of different processing routes.

Accordingly, Ag-ZnO and Ag-CdO composite powders were prepared by five processing routes such as the conventional PM route of blending , spray-coprecipitation , elecroless coating , freeze-drying and mechanical alloying.

The compositions developed through each of these process routes were Ag10CdO , Ag12CdO and Ag 15 CdO in AgCdO category and Ag 7.1 ZnO, Ag 8.6 ZnO,Ag 10.8 ZnO in AgZnO group.

The synthesized powders were examined for their particle size and size distribution , bulk powder properties such as apparent and tap density , scanning electron microscopy, XRD, ESCA, BET surface area and trace impurity of Na and K.In general powders of both AgCdO and AgZnO showed fine particle size (< 10 microns) and size distribution. The SEM micrographs clearly revealed the spongyness of freeze-dried powders ultimately leading to low apparent and tap density.Sameway, the agglomeration tendency of blended powders is also the cause of low apparent and tap density for powders of blending route.The best combination of bulk powder characteristics was attainable for powders synthesized by mechanical alloying, spray-coprecipitation and electroless coating routes in decreasing order of merit.The Na and K levels of powders , particularly those prepared by chemical methods, was controlled below 50 ppm by vigorous washing procedures at an appropriate stage of powder synthesis in each case. The XRD analysis confirmed the formation of Ag and ZnO and Ag and CdO as the only phases in the powders synyhesized by different process routes. XRD was also used as a technique to monitor the process of attrition milling for Ag 10.8 ZnO (MA) and Ag 15 CdO (MA) powders subjected to mechanical alloying.A gradual reduction in relative peak intensity for ZnO and CdO peaks with milling time was observed in XRD profiles of samples of AgCdO and AgZnO drawn at different time intervals indicating alloying tendency. The characterization of electroless-coated powders was done using ESCA. The higher values of relative atomic ratios for Ag to Zn and Ag to Cd as displayed by XPS survey spectra clearly confirm the uniform dispersion of silver on zinc oxide and cadmium oxide particle surfaces in two cases.

The high-density compacts were prepared from powders processed by different routes by using conventional PM cycle of press-sinter-repress-anneal and hot pressing. Final hot-pressed compacts were evaluated for density, microhardness, electrical conductivity, microstructural morphology and electrical contact properties.

Near to theoretical density was obtained for compacts prepared by mechanical alloying, spray-copecipitation and blending routes.Compacts of freeze-drying and electroless coating routes offered relatively low density levels owing to presence of porosity.The porosity in these compacts was mainly due to their powder morphology as exhibited by their SEM micrographs.The microhardness measurements on these compacts gave values comparable to those reported in the literature, with MA route offering the highest value of 106 kg/mm^2. The electrical conductivity values obtained for the compacts of different process routes match well with those reported in the literature and are satisfactory.

Studies on Lithium activation in AgZnO system revealed improved as-sintered density for Li-treated samples besides finer dispersion of zinc oxide in silver-matrix.

The electrical performance evaluation (life testing) for Ag-ZnO and Ag-CdO contacts fabricated from powders of different process routes and subjected to make and break testing under different combinations of current - voltage parameters gave values of weight loss due to arc erosion, contact resistance and consequent temperature rise well within the permissible limits. The results are corroborated by those reported in the literature for similar materials and test conditions.

In summary, the present investigation has clearly demonstrated that AgZnO is an appropriate substitute to toxic AgCdO contact material. Spray-coprecipitation and the mechanical alloying are the powder processing techniques which can offer required contact properties. The improved values of density and microhardness without any loss

of electrical conductivity alongwith a highly uniform dispersion of oxide phase in silver matrix for the contacts prepared by Mechanical Alloying route, brings it out as a future manufacturing technology for processing of Ag-MeO type electrical contact materials.