CHAPTER 5

CONCLUSIONS

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From the present investigations, the following conclusions can be drawn :

1) It is possible to replace CdO by non-toxic ZnO in Ag-MeO type electrical contact materials.

2) Both Ag-ZnO and Ag-CdO have been synthesized as composite powders of desired stoichiometry for comparative study by various processing routes such as spray-coprecipitation, electroless-coating, freeze-drying and mechanical alloying ; over and above the conventional PM process of blending.

3) Composite powders having high apparent and tap density can be produced by processing routes like spray-coprecipitation, electroless coating and mechanical alloying. Whereas the freeze-drying method offers highly spongy powders of relatively low apparent density and tap density with large amount of microporosity.

4) Out of the processing routes employed ; the conventional PM process, coprecipitation and mechanical alloying are able to give near to theoretical density (> 98 % of theoretical) in final hot-pressed compacts. Compared to this, the values reported in the literature for Ag-10 wt%CdO and Ag-15 wt%CdO are 10.0g/cc (i.e.98.04 % of theoretical) and 9.8 g/cc (i.e. 97.42 % of theoretical), respectively [11].

5) The uniform dispersion of oxide phase in silver-matrix has been obtained by spray-coprecipitation and mechanical alloying routes.This is confirmed by their optical

micrographs (shown in Fig. 4.58, Fig. 4.59 and Fig. 4.64) and also by the results of quantitative image analysis. The quantitative measurements for percentage area fraction of oxide phase in Ag-ZnO and Ag-CdO systems offered values of 21.77 % and 16.49 % for compacts prepared by mechanical alloying route whereas the conventional PM route of blending gave values of area fraction as low as 9.66 % and 11.05 %, respectively. This clearly brings out the improvement in oxide phase dispersion achieved by mechanical alloying method.

6) Fine and uniform dispersion of oxide phase in case of electroless coating and MA routes gave improved values of microhardness (85 - 93 kg/mm^2 for electroless-coating and 106 kg/mm^2 for mechanical alloying method). The values reported in the literature [13] for Ag-10 wt % CdO, Ag-13 wt % CdO and Ag-15 wt % CdO in cold-worked condition are 85, 85 and 88 VPN, respectively. As per DODUCO's sales literature also the values of microhardness for PM silver-base contacts of Ag-10 wt % CdO, Ag-12 wt % CdO and Ag-15 wt % CdO compositions at 10 kg load are 60, 65 and 70 kg/mm^2, respectively, in soft condition. Thus mechanical alloying offers an exceptionally greater microhardness.

7) It is possible to attain the levels of electrical conductivity for both Ag-ZnO and Ag-CdO contacts developed in this investigation, comparable to those reported in the literature. For both Ag-ZnO and Ag-CdO contacts prepared by different process routes, 72-91 % IACS value for electrical conductivity was attained in this investigation. Typical reported values of elect. conductivity as per ASM handbook for equivalent Ag-CdO systems range from 55-85 % IACS. R. K. Dubey & coworkers [13] obtained the values of 75, 68 and 65 % IACS for Ag-10 wt % CdO, Ag-13 wt % CdO and Ag-15 wt % CdO, respectively. Likewise, DODUCO sales literature also quotes electrical conductivity values of 86.0 % IACS for Ag-10 wt % CdO ; 82.6 % IACS for Ag-12 wt % CdO and 77.4 % IACS for Ag-15 wt % CdO PM contacts. Thus there is a close

matching between the electrical conductivity values obtained in the present investigation and those reported in literature.

8) Studies on Li-activation in Ag-ZnO system, clearly shows higher as-sintered density for Li-treated Ag-ZnO sample (94.3 % of theoretical for $LiNO_3$ addition as against 66.0 % of theoretical for Li-free sample). Li-activation also gives fine and uniform dispersion of ZnO in silver matrix (as shown by its optical photomicrograph). This can have a definite influence on the contact performance in terms of improved arc erosion resistance and welding behaviour for Li-treated Ag-ZnO contacts.

9) Electrical performance evaluation (life-testing) of Ag-ZnO and Ag-CdO contacts under identical test conditions exhibited a comparable behaviour.The losses due to arc-erosion over 100×10^3 make and break operations for Ag-7.1 wt % ZnO contacts prepared by coprecipitation route ; Ag-7.1 wt % ZnO contacts prepared by electroless coating route and Ag-10.0 wt % CdO contacts prepared by blending route are 17.9 mg, 18.1 mg and 17.4 mg, respectively. In the sameway, corresponding rise in temperature is equal to 5.7^0C, 7.1^0C and 10.4^0C, respectively. Relatively greater temperature rise for Ag-10 wt % CdO contacts prepared by blending route is indicative of their non-uniform mode of erosion as compared to those of Ag-7.1 wt % ZnO contacts prepared by coprecipitation and electroless coating routes.Thus in respect of contact resistance property, the contact system Ag-ZnO is even better than Ag-CdO.

The contact materials of both Ag-ZnO and Ag-CdO group developed in this investigation exhibited excellent anti-welding behaviour. No welding of contacts was noticed during or after 100×10^3 contact operations.

The contact performance of contact-tips developed in this investigation is comparable to those reported in the literature as well. The weight loss due to arc-erosion for Ag-8.6 wt % ZnO contacts of coprecipitation route (developed in present investigation) and tested at 30A / 415V / 0.98 cos φ / 3 phase over 100×10^3 make and break operations is 52.0

mg. Studies on Ag-12 wt % CdO contacts at 20A / 230V / 1.0 cos φ / 1Ø phase over 100×10^3 operations carried out at LCIE, France [142], reports arc erosion loss of about 55.0 to 60.0 mg.

10) It is apparent from the results of this investigation that Mechanical Alloying route offers the best combination of physical, microstructural and electrical contact properties. In specific, the density of the order 99.3 - 99.6 % of theoretical, the microhardness of 106 kg/mm^2 at 65 g load and the electrical conductivity values equal to 72 - 74 % IACS are obtained for Ag-10.8 wt% ZnO and Ag-15 wt% CdO contacts processed by mechanical alloying method. The typical values reported in the literature for Ag-15 wt % CdO PM contacts are, density of 9.8 g/cc (97.4 % of theoretical), hardness in as-annealed condition equal to 60 kg/mm^2 and electrical conductivity value of 75 % IACS. The Ag-10.8 wt% ZnO contacts prepared by MA route also successfully passed through electrical performance test as per IEC 947-4-1. In view of this, MA appears to be the probable new technology for processing of Ag-MeO composite powders for electrical contact applications. Because of its operational cleanliness, simplicity and expected lower processing cost, it is likely to emerge as a novel commercially viable technology in the field of electrical contact materials.