

# Silver- Molybdenum Disulfide Electrocomposites

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Silver-molybdenumdisulfide electro-composites were produced from a cyanide based electrolyte. The percentage incorporation of the dispersoid in the deposit and the effect of thallium ion addition on their co-deposition were evaluated. Hardness and wear properties of the deposits were evaluated. A thin layer of molybdenum-di-sulfide was also produced on pure electrodeposited silver surface and the coatings were compared.

*Key words:* electro-composites, lubricant coatings, addition agents, hardness, wear resistance, Si-MoS<sub>2</sub>

## Introduction

An important property of the plated electrical contacts is the conductivity of the deposit. Equally important, especially in the case of plated sliding contacts, is the wear resistance. It is difficult to combine the high conductivity with high sliding wear resistance. One possible way of reducing the adhesive wear is to apply a monomolecular layer of a nonmetallic substance (grease or oil) on the metal contact surface. However, for some sliding contacts, such thin layer may prove futile and under heavy load or high temperatures, the film could be irreversibly damaged [1].

Valve mechanisms operating at high temperatures as in space and nuclear applications must operate reliably [2]. In general, the expected number of cycles is limited, but these operations must be performed absolutely trouble free even after a long idle period. Electrodeposited silver finds application in such areas with a thin molybdenum disulfide coating produced by sputtering technique [3], as a top layer to reduce the adhesive wear. We have attempted to reduce the adhesive wear by electroplating composite coating of silver with incorporated molybdenum disulfide from a cyanide electrolyte.

## Experimental

A cyanide bath and a strike bath of the following composition were used for the studies.

Strike bath	
Silver cyanide:	2-5 g/l
Potassium cyanide:	75-90 g/l
pH:	10.5
Current density:	3.0 A/dm <sup>2</sup>
Duration:	2 minutes
Plating bath	
Silver cyanide:	25-35 g/l
Potassium cyanide:	50-60 g/l
Potassium carbonate:	40-50 g/l
PH:	10.5-11.5
Current density:	3.0 A/dm <sup>2</sup>
Duration:	10-15 minutes

Analytical grade molybdenum disulfide was used as the particulate material. A silver foil was used as the anode and a copper sheet was used as the substrate with due pretreatments and strike plating. Experiments were conducted on 3 x 3 cm<sup>2</sup> panels initially to estimate the percentage incorporation of the particles in the deposit and then on 10 x 10 cm<sup>2</sup> area to determine the wear loss. Co-deposition was carried out in the vertical as well as in the horizontal plane and the effect of operating conditions and concentration of the dispersoid on the percentage incorporation in the deposit was estimated. The composition of the deposit was estimated by anodically stripping the deposit in sulfuric acid - nitric acid mixture [4] and then estimating the silver by EDTA method [5]. The effect of addition of thallium chloride on the percentage

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incorporation was studied [6]. The hardness of the deposits was measured by Knoop indentation method at a load of 20 grams using a metallurgical microscope and the wear resistance was estimated as the weight loss per 100 cycles at a load of 1 kg.

MoS<sub>2</sub> coating was also produced by the electrochemical method, potentiostatically using a solution of ammonium molybdate and ammonium sulfide at pH 8.0 in the potential range -600 to -950 mV. The film applied on a pure silver deposit was also tested for its wear property.

## Results and discussion

Table 1 shows the effect of MoS<sub>2</sub> concentration in the bath on its percentage incorporation in the deposit at various current densities in the vertical mode. Unlike the nickel and copper composites, where the inclusion percentage is very much low, it is much higher in this system, even at a concentration of 25 g/l of MoS<sub>2</sub> in the solution. There was no dramatic increase in the percentage incorporation by doubling its concentration. This confirms that co-deposition occurs through adsorption of the particulate material [7]. With increase in operating current density, the percentage incorporation shows a slight increase.

Table 1. Effect of MoS<sub>2</sub> concentration in solution on the percentage incorporation in the deposit

Current Density (A/dm <sup>2</sup> )	MoS <sub>2</sub> : 25 g/l		MoS <sub>2</sub> : 50 g/l	
	Horizontal	Vertical	Horizontal	Vertical
0.5	12.61	—	14.64	—
1	12.63	9.6	15.32	6.5
1.5	14.29	10.88	17.73	7.65
2	16.4	—	19.3	—

Table 1 also shows that the percentage incorporation in the deposit increases tremendously in the horizontal mode. However, the deposits were powdery in nature and not suitable for conducting any tests.

Table 2. Effect of additive concentration on the percentage incorporation in the deposit

Current density (A/dm <sup>2</sup> )	MoS <sub>2</sub> : 25 g/l		MoS <sub>2</sub> : 50 g/l	
	TiCl (2 g/l)	TiCl (1 g/l)	TiCl (2 g/l)	TiCl (1 g/l)
	MoS <sub>2</sub> (%)	MoS <sub>2</sub> (%)	MoS <sub>2</sub> (%)	MoS <sub>2</sub> (%)
1	12.16	20.91	16.93	21.2
1.5	14.56	24.1	17.92	25.1
2	16.43	27.19	19.66	30.36

In composite plating, it is often reported that certain additives are helpful in increasing the incorporation [6]. For example, cations like thallium, rubidium etc. are added to enhance the co-deposition in an acid copper bath. It is proposed that by selective adsorption on the surface of the particles, these ions change the surface charge on the particles and make their co-deposition with the metal easy. As understood from the results given in Table 2, the addition of 2 g/l thallium gives rise to a significant increase in the inclusion percentage.

Tables 3 and 4 show the rate of deposition of the silver composite and their hardness. A slight increase in the hardness value was observed with MoS<sub>2</sub> incorporation and thallium ions helped in further increasing the hardness. With high MoS<sub>2</sub> incorporation obtained using the horizontal mode, the readings were not consistent due to the powdery nature of the deposits. The wear rate of the deposits, as given in Table 5 shows that there is improvement on the wear resistance of the deposits by the inclusion of MoS<sub>2</sub>. But the deposits obtained in presence of 2 g/l thallium ion show a high wear rate. Best results were obtained by having a thin film of MoS<sub>2</sub> on pure silver deposit and work in this line needs further investigation.

Table 3. Effect of addition agent concentration on the rate of deposition of silver composite

Current density (A/dm <sup>2</sup> )	Thickness (μm/hr) at MoS <sub>2</sub> : 25 g/l additive concentration in g/l			Thickness (μm/hr) MoS <sub>2</sub> : 50 g/l additive concentration in g/l		
	0	1	2	0	1	2
0.5	26.67	—	—	26.6	—	—
1	54.36	48.9	43	53.3	48	41.7
1.5	70.05	66.7	53	68.5	62	51.1
2	104.60	77.6	73	100	76	68.9

Table 4. Effect of additive on the hardness of silver composite

Current density (A/dm <sup>2</sup> )	Hardness, Knoop at MoS <sub>2</sub> : 25 g/l at additive concentration in g/l			Hardness, Knoop MoS <sub>2</sub> : 50 g/l additive concentration in g/l		
	0	1	2	0	1	2
0.5	77.8	—	—	77	—	—
1	112	118	122	98.8	76	76.2
1.5	89.3	130	140	87.3	87	65.1
2	74.4	120	124	76	75	53

Table 5. Wear resistance of silver composite

No.	Deposit	Wear loss (mg)
1	Silver	30.2
2	Silver-MoS <sub>2</sub> (25 g/l)	23.5
3	Silver-MoS <sub>2</sub> (50 g/l)	24.4
4	Silver-MoS <sub>2</sub> (50 g/l) + TiCl (1 g/l)	20.6
5	Silver-MoS <sub>2</sub> (50 g/l) + TiCl (2 g/l)	28.3
6	Silver + MoS <sub>2</sub> thin film	16.5

## Conclusion

Silver-MoS<sub>2</sub> coating showed higher hardness and wear resistance compared to pure silver deposits. This coating can be used in applications, where high electrical and thermal conductivity along with lubricity and hardness are required.

## References

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