# The role of mass transfer layer on the tribological characteristics of silver-coated surfaces

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Wear map of silver coatings on AISI 52100 has been constructed to delineate the wear transition behavior with the change in operating conditions in various environments. Three main regimes were clearly identified: (i) elastic/plastic deformation of silver coating without failure, (ii) mild wear regime after initial failure of silver coating and (iii) severe wear regime. In the mild wear regime, the contact surfaces were covered with transfer layers of agglomerated wear particles. The transfer layer acted as a protective layer and resulted in low friction even after the initial failure of the coated films, whose characteristics were strongly dependent on both the operating and environmental conditions. Also, the existence of the critical sliding speed, above which no transfer layer was able to form, was discussed in the work.

***Keywords:*** *Wear map; Transfer layer; Functionally gradient film; Critical velocity*

## 1. Introduction

It has long been recognized that initial failure of coating is the end of service life. Therefore, the transfer layer, which occurs after the initial failure of coating, has been little focused till recent year. During the last decade, the transfer layer has been one of great concerns to many tribologists because it changes the friction and wear characteristics very seriously. Many of works have focused on the generation mechanism of transfer layer [1-3] and the role of the transfer layer on friction and wear [4-6]. Yet all of those works dealt in a specific point of view under certain operating conditions. Therefore the generation mechanism and the role of transfer layer need more elaborated works.

In this work the tribological characteristics of silver transfer layers were focused. Functionally gradient silver coating was tested in various ranges of load and speed and the results were summarized in a wear map constructed with the axes of contact pressure and sliding speed.

## 2. Experimental details

Pure (99.99%) silver was coated on the hardened AISI 52100 steel disks with a functionally gradient coating method [7] with the thickness of 1 μm. Friction and wear characteristics of the coating were evaluated with ball-on-disk type tribo-testers (macro tribo-tester [8] and miniature tribo-tester [8]) all of which unidirectional dry sliding was applied in the load range of 0.02 N ~ 17.64 N and the speed range of 20 mm/sec ~ 1000 mm/sec for a fixed sliding distance of 1000 m under ambient air and vacuum.

## 3. Results and discussion

The tests were performed in various ranges of load and speed under ambient air and vacuum, and the characteristic wear regimes were summarized in a wear map constructed with the axes of contact pressure and sliding speed as shown in Fig. 1. Maximum Hertzian contact pressure and sliding speed were selected as the axes of the map because the P×V (pressure×speed) value corresponds to the mechanical input energy to the coating films. All of the wear coefficients and the coefficients of friction were plotted numerically at the different combinations of contact pressure and sliding speed. Based on the relative magnitude of the given wear coefficients, 3 different characteristic regimes (regime I, regime II and regime III) could be identified as shown in Fig. 1. In the regime I, silver film sustains the applied load without any failure of the coating. Regime II demarcated the region where relatively low wear coefficients (order of $10^{-4}$ ~ $10^{-5}$) were still sustained after the silver coating failed.

In this regime, wear particles were generated after the failure of silver coating and they formed the transfer layers.

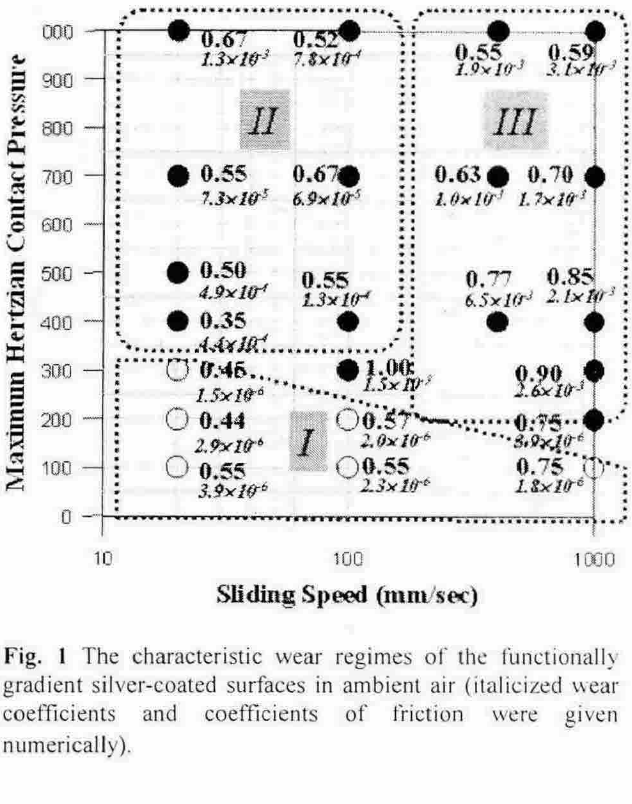
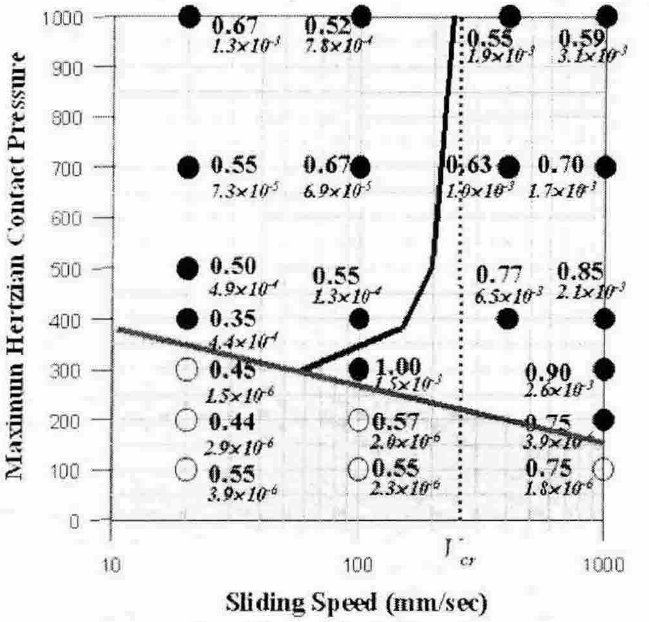
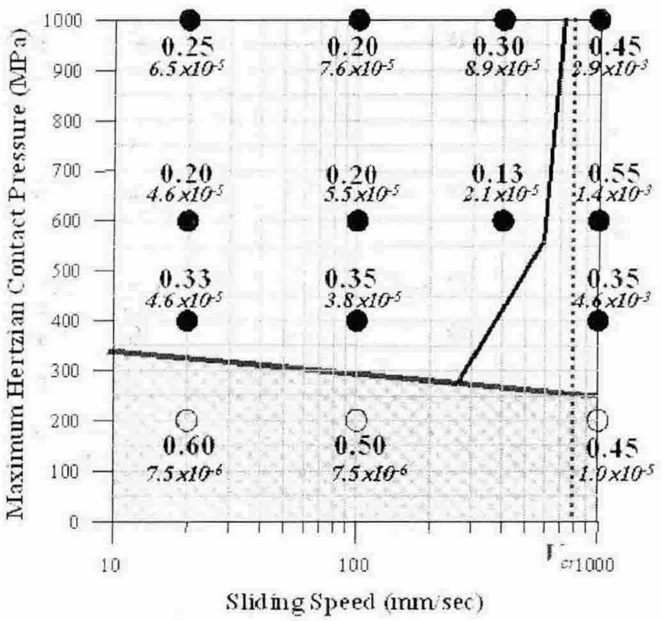



**Fig. 1** The characteristic wear regimes of the functionally gradient silver-coated surfaces in ambient air (italicized wear coefficients and coefficients of friction were given numerically).

The transfer layers acted as a protective layer and they decreased the wear and friction to a low and stable value. Therefore, it was found that the formation of transfer layer provided beneficial effects to the contact surfaces even after the coating film failed. Regime III was demarcated the region of relatively high wear coefficients ($K > 10^{-3}$). In this regime, transfer layers could not be observed after the failure of the coating so the friction and wear were higher than those of Regime I and Regime II.




(a) ambient air




(b) vacuum

**Fig. 2** A wear map of the functionally gradient silver coating in ambient air and in vacuum (italicized wear coefficients and coefficients of friction were given numerically).

Based on the above characteristic regimes (I, II and III), a wear map of the functionally gradient silver coating was constructed as shown in Fig 2. In both of the ambient air and vacuum, it was found that the border between regime II and regime III in Fig. 11 is mostly affected by the sliding speed It also suggested that a critical sliding speed ($v_{cr}$) exists in the formation of transfer layer, above which no material transfer is able to form.

## 4. Conclusions

The tribological role of transfer layer of silver-coated surfaces was summarized as follows.

(1) Silver transfer layers could protect the silver-coated surface beneficially even after the initial coating failure occurs.
(2) Wear maps of silver coating films were constructed using the axes of contact pressure and sliding speed, where 3 different characteristic wear regimes were clearly identified such as regime I (no failure, mild wear), regime II (dominant region for transfer layer, moderate wear) and regime III (no transfer layer, severe wear).
(3) The formation of transfer layer was strongly affected by the operating conditions, especially by the sliding speed. Hence it was suppressed when the sliding speed was high and above a critical sliding speed, no transfer layer was able to form.

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