THE ROLE OF TRIBO-CHEMICAL PROCESSES IN THE FRICTION AND WEAR BEHAVIOR OF CONTACTS IN NANOLITHOGRAPHIC SYSTEMS

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ABSTRACT
Understanding the fundamental aspects of the friction and wear mechanisms that occur in several areas of the chip production process in photolithography systems, is highly relevant to solving the positioning challenges that currently limit the minimum achievable feature size. Variations in friction and surface wear at critical points in the photolithographic process (e.g. the interface between the wafer table and the silicon wafer substrate), can lead to nm-scale distortions in alignment, inhibiting improvements in overlay performance and as a consequence, directly contributing to the fading of Moore's Law.

In order to experimentally investigate the variations in friction and surface wear of this tribological system, model experiments were performed in ambient conditions, using silicon carbide (SiC) and silicon (Si) as the two selected industrially relevant contacts in a dry sliding ball-on-flat configuration. Focus was placed on furthering the understanding of the role played by tribo-chemical processes, namely, the parameters that govern the formation of tribofilms and the subsequent influence of these layers on the system surface friction and wear.

The sliding mode (unidirectional and reciprocated) and SiC surface roughness were varied in order to expose the impact of these particular parameters on tribofilm growth, friction and wear. Both sliding surfaces were characterized in terms of their morphology (optical profilometry and scanning electron microscopy) and chemical composition (energy dispersive x-ray spectroscopy) before and after wear testing.

Post-wear analysis revealed in all cases, the formation of SiO_x inside the wear track on the Si wafer. A clear correlation was also found between SiO_x growth, ploughing surface interactions, and the friction force of the system, as shown in Figure 1. The sliding mode was seen to influence the nature of SiO_x growth, and subsequently the surface friction and wear rate of both the contacts. Extensive SiO_x growth resulted in accelerated wear of the SiC counter surface, thus highlighting the potential influence of tribo-chemical processes in nanolithography.

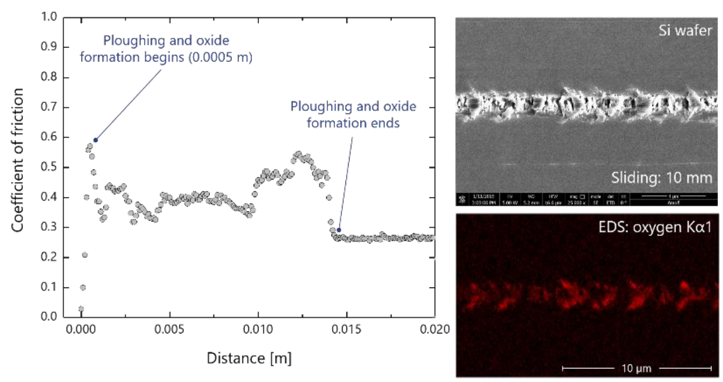

Fig.1 Coefficient of friction as a function of sliding distance for SiC-on-Si contacts. SEM image and corresponding EDS map illustrating ploughing and oxide formation at 10 mm sliding.

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