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Moisture Dependent Wear Mechanisms of Gallium Nitride

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Abstract

Ultralow wear nature of gallium nitride (GaN) has been revealed recently. The wear rate for GaN has a significant dependence on humidity, ranging from 9×10^{-9} mm^3/Nm to 9.5×10^{-7} mm^3/Nm; the mechanisms responsible for this variation in wear remain unclear. Here, we performed reciprocal sliding test on GaN under different environments and characterized the chemical compositions of corresponding worn surface by energy dispersive X-ray spectroscopy (EDS). We show that the surface chemistry of GaN responded differently to various testing environments; this gave rise to the wear rate of GaN spanning over orders of magnitude. Additionally, the EDS conducted on the countersample (alumina probe) clearly evidenced a material transfer from GaN to the ruby countersample. Atomic force microscopy (AFM) and secondary electron microscopy (SEM) inside the wear scar indicated a grooving abrasion wear mechanism of GaN tested under humid environment and adhesive wear mechanism for dry nitrogen testing environment; this is confirmed by SEM/EDS of the ruby probes. In addition, transmission electron microscopy (TEM) was employed to image the defects formed underneath the worn surface, due to the tribological sliding, and the results suggested a possible evolution of wear debris formation.

1 Introduction

Moisture effect on various materials has been studied for decades, including wear of glass [1], and mechanisms of moisture effect on fracture and wear performance of several ceramics, like Si, SiC, Si_3N_4, SiO_2, ZrO, Al_2O_3, GaAs, etc. [2–18] and ceramic filled polymers [19–22]. Wiederhorn published a seminal work on how moisture assisting crack growth on glass and sapphire [1]. He discovered that the measured crack propagation velocity was a function of stress and water vapor concentration. Gee looked into the tribochemical reaction during wear of α-alumina and pointed out that the wear rate of alumina decreased with the increasing of humidity, yet very little effect was found of humidity on friction. It is due to the formation of thin