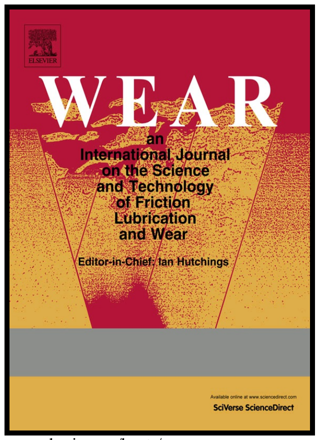
Author's Accepted Manuscript



www.elsevier.com/locate/wear

Tribological Performance of Monolithic Copper Thin Films During Nanowear

Bradley M. Schultz, Nan Li, David R. Economy, Julia L. Sharp, Nathan A. Mara, Marian S. Kennedy

PII: S0043-1648(17)30311-3
DOI: https://doi.org/10.1016/j.wear.2017.10.005
Reference: WEA102269

To appear in: *Wear*

Received date: 21 February 2017
Revised date: 21 August 2017
Accepted date: 6 October 2017

Cite this article as: Bradley M. Schultz, Nan Li, David R. Economy, Julia L. Sharp, Nathan A. Mara and Marian S. Kennedy, Tribological Performance of Monolithic Copper Thin Films During Nanowear, *Wear,* https://doi.org/10.1016/j.wear.2017.10.005

Tribological Performance of Monolithic Copper Thin Films During Nanowear

Bradley M. Schultz[a], Nan Li[b,c], David R. Economy[a], Julia L. Sharp[d], Nathan A. Mara[b,c], Marian S. Kennedy[a,e*]
[a]Department of Materials Science & Engineering, Clemson University, Clemson, SC 29634 USA
[b]Center for Integrated Nanotechnologies, Los Alamos National Laboratory, Los Alamos, NM 87545 USA
[c]Institute for Materials Science, Los Alamos National Laboratory, Los Alamos, NM 87545 USA
[d]Department of Mathematical Sciences, Clemson University, Clemson, SC 29634 USA
[e]Center for Optical Materials Science and Engineering Technologies (COMSET), Clemson University, Clemson, SC 29634 USA
bradley.schultz.31@gmail.com
mskenne@clemson.edu
[*]Corresponding author. Tel.: +864 656 5349.

Abstract
Mathematical models suggest that the strain along the film formed by parallel passes of a nanoindentation probe in contact with the film can be either homogenous or heterogeneous, depending on contact pressure and spacing between passes. In this study, a 1 µm copper thin film was worn with a cono-spherical diamond probe with normal loads ranging from 25-800 µN and wear box edge lengths of 40, 60, and 80 µm. The nanoindenter counterface was rastered across the surface to mimic dry sliding wear. To determine potential strain field changes, 10-step quasi-static indents (200-2000 µN) were performed using nanoindentation inside the wear boxes created at various loads to determine if a strain field alteration could be observed in changes in hardness of the copper thin film. It was shown that there was a softening effect in the hardness for normal loads < 400 µN used during nanowear compared to the as-deposited copper. Normal loads ≥ 400 µN had a similar or higher hardness than the as-deposited copper. This is believed to have occurred due to a relaxation in the residual stresses created during deposition in the copper thin films at lower loads, which caused a decrease in hardness. Conversely, at the higher loads, increased deformation leads to an increase in hardness. Additionally, all of the wear boxes displayed a higher estimated strain hardening exponent than the as-deposited material.

Keywords
Nanotribology; Nanoindentation; PVD coatings; Hardness; Sliding Wear

1. Introduction

For industrial products and applications, engineers need to be able to control wear at the nanoscale and accurately predict component lifetimes. To achieve this end, fundamental experimental and theoretical studies on nanotribology have significantly increased in recent years [1, 2]. Since both the mechanisms and magnitude of the wear events are specific to the system's parameters, this work seeks to address wear that could occur in electronic components whose surfaces are in contact with a secondary surface during use. Examples of this type of contact might include the insertion of electrical connectors onto pads (pins) and microelectromechanical systems (MEMS) devices that have moving or rubbing surfaces [3, 4]. While all these systems might experience wear, the loading conditions are uniquely situated for each. Electrical connectors often undergo either linear sliding contact by the repeated insertion and removal of the plug-in or repeated relative surface motion caused by vibrations during operation. Both loading conditions can cause damage or wear, respectively referred to as sliding or fretting wear [5–7]. To replicate these loading conditions, researchers are either developing new pieces of characterization equipment or modifying existing characterization systems that were previously used for small scale normal loading, such as