ABSTRACT
Surface modification and performance depend largely on the properties of surface atoms and structures. Fundamental investigation of friction was conducted in a Cu-Al sliding system. Deformation, wear, and transfer were studied. Detailed study was focused on friction-induced phase transformations. Surface characterization was carried out using an atomic force microscope (AFM). The debris analysis was done using a transmission electron microscope (TEM). Results showed that debris formed during sliding were amorphous. On the wear track, there is indication of surface melting and hardening. This presentation will discuss wear mechanisms involved in oxidation and property-performance of metallic materials.

INTRODUCTION
During sliding, the structural as well as chemical changes occur between interfaces of two sliding bodies. It was reported that a thin film is formed after polishing [1]. This layer is amorphous [2] and it was induced through rapid solidification of locally melted asperities [2, 3]. Other work reported that during sliding the nano crystalline materials could be developed [4-7]. These have been experimentally proven or predicted by Molecular Dynamics (MD) simulations [7]. In the present study, the friction induced phase transformations during severe sliding wear of Cu-Al was studied using pin-on-disc rotating tribometer.

RESULTS AND DISCUSSION
In the present study, the unworn and worn surfaces of copper were imaged using contact mode configuration of the AFM. Figure 1 a, and 1 b show the topological image and friction force microscope (FFM) image respectively of unworn surface of copper. Figure 2 a, and 2 b are topology and FFM image for the worn surface respectively. Debris formed during the sliding was collected and analyzed using TEM. Figure 3 shows the TEM micrograph of debris and inset of the selected area diffraction pattern (SAD) taken on the debris surface. The selective area diffraction pattern (SAD) showing the possible nano nuclei shown in inset.

Analysis of the surface using friction force microscopy showed that the surface friction property of copper was different from that of its original surface. Due to sliding, copper surface was worn which is shown in Fig. 2 a (i.e. topological image). The friction change on the surface which is shown in Fig. 2 b might be due to the surface properties change.

The materials used in tribological applications are mostly elastoplastic in nature. Due to continuous load and frictional forces on the surface, these materials deform plastically. The subsurface deformation and the crack nucleation and growth under the surfaces are also explained by N. P. Suh. [8]. He reported the dislocation movements under the surface. These phenomena can change the surface properties as we have seen in the frictional force microscope image. It is possible that the asperities on the surface melt during sliding [2, 3], due to the rapid cooling the molten parts solidified which might show different friction. The work hardening was possible through continuous sliding. This is seen in the change of AFM friction image on the surface.

The debris analysis showed that there is amorphous debris formed during severe sliding of Cu and Al. In metals such as Al, Si, Cr, Ge, Nb, and Ta, oxidation initially takes place forming amorphous films and then these films transfer into crystalline depending upon temperature and time [9, 10, 11, 12, 13]. The reason of the initial state of crystallization or amorphization was due to the crystallization energy [14]. It is predicted that the amorphous debris formed is predominantly of amorphous alumina.

CONCLUSIONS
Dry sliding experiments were conducted on Al and Cu. The amorphization, melting, and hardening were found in wear debris and on wear track. These surface changes were reflected in the friction map under AFM analysis.
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REFERENCES