INVESTIGATION OF THE ElASTOPLASTIC DEFORMATION BEHAVIOUR BY NANO SCRATCHING METHOD

Sumaiya Islam, Raafat N. Ibrahim

Department of Mechanical & Aerospace Engineering, Monash University, Clayton, Victoria 3800, Australia.

Introduction

Copper and Nickel have a lot of advantages for using in the manufacturing of electronics components [1]. Electroplated copper provides excellent electrical conductivity properties for applications in the field of electronics and telecommunications and nickel itself used in magnetic micro actuators. Thus it is important to investigate the nano machining operations on copper and nickel for nano level manufacturing and their elastoplastic characteristics.

Elasto-plastic behaviour of silicon and boro silicate surfaces have been reported by varying the tip geometry and tip orientation using an AFM [2-5]. These studies treated the sample as amorphous and disregarded the effect of crystal orientation and crystal structure . The results showed that the elastic recovery depends on the tip shape and normal force. The elastic recovery was measured only by the variation of the normal force. Therefore the effect of the variation of the depth of cut was not considered to calculate the elastoplastic deformation behaviour.

The objective of this study is to address the effect of depth of cut by investigating the elastoplastic deformation behaviour and piling up effect of the coated material surfaces by the nano scratching method using the Tribo indenter. The post profile scratches were used to calculate the elastic deformation and the piling up volume. The piling up volume was measured to evaluate the effect of plastic deformation of the material.

Experimental Setup

Copper and Nickel were used as the substrate materials in this study. Before coating, the substrate material was properly polished to make the surface flat and parallel. Then it was cleaned and dried by using ethanol spray gun. After cleaning the substrate, Cu and Ni were electroplated at a current density of 3.5 Amps/dm² and a deposition rate of 0.8 μm/minute to form the respective coatings. In the electroplating process, an electronic grade metal sheet of the coating material was used as the anode, while the substrate acted as the cathode. The coating thickness was chosen to be 20μm and was achieved by controlling the duration of the electroplating process.

In this experiment, nano scratches were generated using the Tribo Indenter^{R} (Scaning nano indenter) utilizing the displacement control mode. The diamond Berkovich tool having a tip radius of 100 nm was used for the scratching purpose and in situ observation was performed. All experiments were performed under room temperature and normal atmospheric conditions with temperature range of 20-24°C and relative humidity range of 45-50%. The topographic scanning method was employed to analyse the depth of the machined surface. The area of the topographic measurement was 10x10 μm^2. During scanning of the surface by Tribo indenter, 20 μm/s tip velocity and 1 Hz scan rate were used. Four different depths of cut (50nm, 100nm, 150nm and 200nm) were used and scratch length and feed rate were kept constant at 10 μm and 0.33 μm/s respectively. Before doing any scratch the roughness of the surface was measured. The measurement of the average surface roughness for the investigated samples were in the range of (0 .7- 2) nm.

Result and Discussion

After the scratching operation, the obtained machined depth was determined using the scanner of the Tribo Indenter. Figure 1 shows the variation of the obtained depth of the machined area with respect to the applied depth of cut. The depth of the machined area increased with the increase of the depth of cut. However a higher normal force was generated for Ni compared to Cu for the same depth of cut, but the depth of the machined area was found to be larger for Cu than Ni. This indicates that Cu had exposed to higher plastic deformation, and therefore consequently lower elastic recovery was achieved.

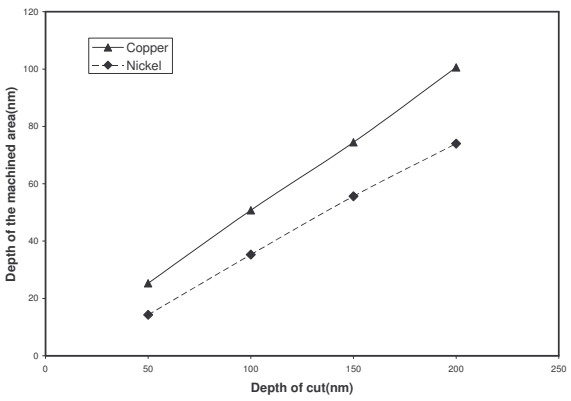

Fig.1 Variation in the obtained depth of the machined area with applied depth of cut.

Figure 2 shows the variation in the elastic recovery (%) with respect to the depth of cut. For both materials, the ratio of elastic recovery decreased with the increase in the depth of cut, which is due to increase of the normal force. However the elastic recovery was lower in the case of Cu compared to Ni.

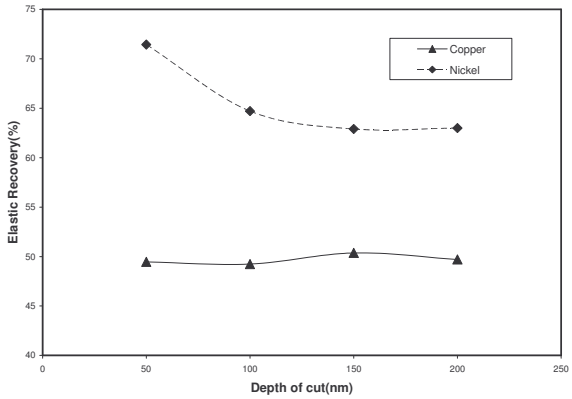

Fig.2 Variation in the elastic recovery with depth of cut for various coatings.

Fig 3 shows that the piling up volume always generated at one end of the scratch length. Piling up volume generated at the edge of the cutting tool. Cutting tool (Berkovich tip) used in this experiment has an asymmetric shape[6]. So the cutting edge faces one side of the scratch length. Therefore the piling up volume occurs at one side of the scratch length. It can be observed that the piling up was larger for Cu than Ni because of relatively higher plastic deformation.

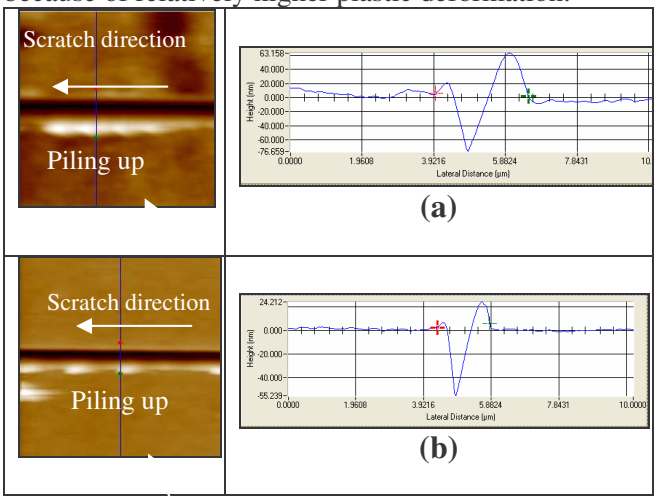

Fig. 3 Machined surface images and transverse cross sectional profiles of (a) Cu and (b) Ni for 150nm depth of cut.

Figure 4 shows the changes in the piling up volume with the depth of cut. The piling up volume was larger for Cu compared to Ni, and it increased with the increase in the depth of cut. This establishes that a higher plastic deformation leads to an increase in the piling up volume of the scratched profile.

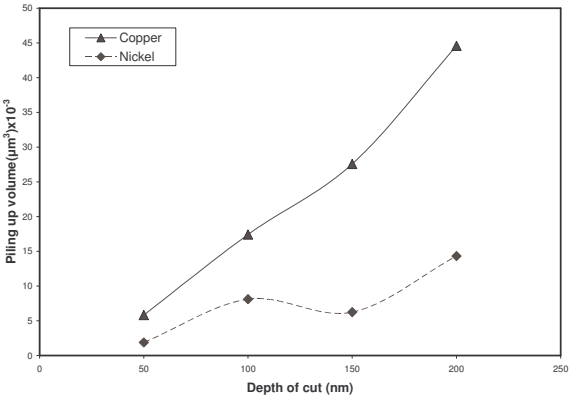

Fig.4 Variation in the piling up volume with change in depth of cut.

Conclusion

In nano scratching operation, the elastic recovery of the material depends on the material property. The elastic recovery decreases with the increases of the depth of cut for both materials. The elastic recovery is 20% higher for Ni than Cu after single scratch operation.

Piling up occurs due to plastic deformation of the material during nano scale scratching. The width of the scratched surface and piling up volumes indicate that the plastic deformation is higher for Cu compared to Ni for the same depth of cut.

The conclusion of this study is that Ni experienced higher elastic recovery as well as lower plastic deformation compared to Cu due to higher hardness.

References

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