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Study the Performance of Cu-Tio_2- Al_2O_3 Solution on Cutting Tool with Nano Coating

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Abstract

It has been well established that advanced surface coatings on cutting tools improve wear resistance by modifying the contact conditions between the chip and tool interface. As a result of the recent developments in cutting tool industry, coated tools have made a significant contribution to the metal cutting operations in terms of tool life, cutting time and machining quality. The challenge of modern machining industries is focused mainly on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product. In general, the most important point in machining processes is the productivity, achieved by cutting the highest amount of material in the shortest period of time using tools with the longest life time. In the present work parallel plate electro deposition process employed to improve the surface mechanical properties of copper without adversely effecting it's electrical and thermal conductivities, by developing a layer of nano composite coating consisting of copper matrix and ultrafine ceramic oxide particles (TiO2, Al2O3) on surface of copper. And to determine the optimized current density and particle concentration in the bath with the coating results achieved.

Keywords: : Nano coating , TiO2, Al2O3

1. Introduction

The cutting tool industries are constantly facing the very common industrial challenge of reducing cost of machined parts and at the same time improving the quality of the machined surface. These issues are generally addressed by improving cutting tool materials, applying advanced coating, improving the geometry and surface characteristics of the cutting tools, optimizing machining parameters [1]. The need for the use of newer cutting tool materials to combat hardness, wear situation has resulted in the emergence surface coatings, which contributes in reducing cost per machined parts through increasing productivity and extending tool life. The benefits of advanced coatings are of higher hardness, low friction at the chip tool contact, higher wear resistance, high hot hardness and high thermal and chemical stability. The machined surface quality with the coated cutter can also be improved by avoiding any built-up edge due to the reduced friction between the tool and work piece.

2. Experimental Procedure

For the deposition of Cu-TiO2 and Cu-Al2O3 composite coatings, copper was selected as substrate. The substrates were collected from hot rolled copper strip by cutting it into averagely 20mm×15mm size pieces. The approximate dimensions of the substrates were 20mm×15mm×3mm. Then the substrates were mirror polished by grinding on belt grinder for oxide layer removal, then on emery papers (1/0, 2/0, 3/0, 4/0), then rough cloth polishing in which Alundum was used as abrasive agent. Finally the substrates were fine polished by fine cloth in which diamond paste was used as polishing agent. Then the substrates were cleaned with soap and then washed with water. Ultrasonication of the substrates was done for 10 minutes by using deionized water and acetone for the removal of fine particles which adsorbed on the sample surface during the polishing. In this way the mirror polished substrates were prepared for deposition. Holes were made on the samples to dip the samples in the electrolyte solution and to supply current by attaching copper wire to the hole.

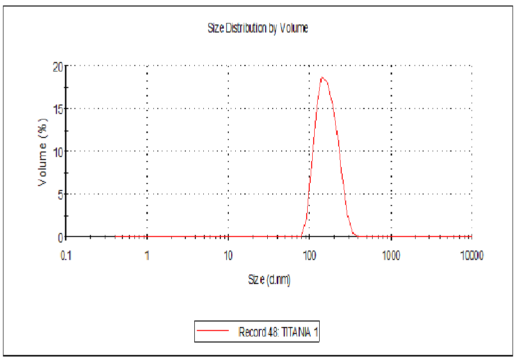
3. Experiment Analysis

X- Ray Diffraction studies of all the deposited samples were performed by using, Philips X'Pert system with Cu Kα radiation (λ= 1.5418A°) to judge the phases formed, to calculate the crystallite sizes and also to determine the Relative Texture Coefficient (RTC) of the deposits. The same was also done for pure copper sample which was used as substrate and for raw powders of TiO2 and Al2O3. The XRD was carried out with 2θ range of 20°-100° with scan rate of 3 degrees per minute

Microhardness of the composite coatings (Cu-TiO2 & Cu-Al2O3), pure copper coatings and the pure copper (substrate) were determined by using LECO LM700 michrohardness tester which is shown in Figure 3.3. The machine have minimum 1gf and maximum 1000 gf load, Dwell time5-99sec and Knoop or Vicker s indenter is included . The test was carried out with 10 gf load for 15 seconds to ensure that the indentation is up to the coating surface only.

4. Results

The below Figure 4.1 (a) & (b) shows the particle size distributions of TiO2 and Al2O3 powders obtained by using Malvern Zeta sizer. From the figure it can be seen that no sharp peak was observed in both the cases, it indicates that a range of different sized particles were present in the bulk powder. In case of titania minimum size was observed at 91 nm and maximum 295 nm. But higher volume percentage of particles having sizes between 105 nm to 190 nm. From the cumulative study the mean size obtained for TiO2 was 202 nm. In case of Alumina, the minimum size observed was 190 nm and the maximum size was 342 nm, but the higher volume percentage of particles was having sizes between 220 nm to 295 nm. The mean size obtained for Al2O3.



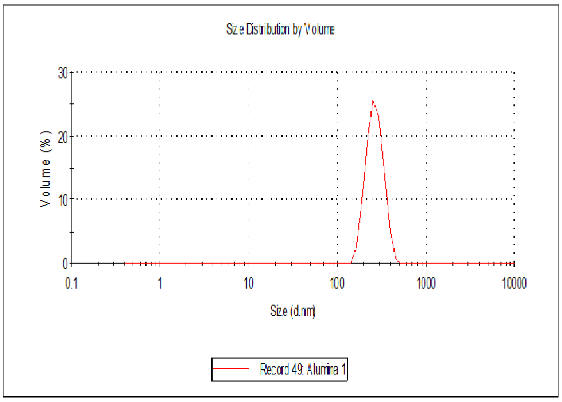


Figure 4.1: Particle size distribution of (a) TiO2 powder (b) Al2O3 powder.

Zeta potential of TiO2 & Al2O3 ultrafine particles in de-ionized water at different *pH* values was measured to determine the iso-electric point for stable suspension by using Malvern Zetasizer nano series Nano- ZS model instrument prior to the electrodeposition. From the below Figure 4.2(a) it can be observed that the iso-electric point of TiO2 was around 4.2 in *pH*, where as it is around 5.5 [63] according to the literature. The *pH* maintained in our case for Cu-TiO2 system was around 2.0 *pH*, which was lower than the obtained iso-electric point *pH*, which signifies the acidic nature of the solution and the particles were positively charged in the suspension. Similarly from Figure 4.2 (b) the iso-electric point of Al2O3 was observed around 5.3 in *pH*, according to literature it is 8-9 [64] in *pH*. In our case for Cu-Al2O3 system the *pH* was maintained at 4.0 *pH*, which also signifies the acidic behavior of the solution and the particles were positively charged in the suspension.

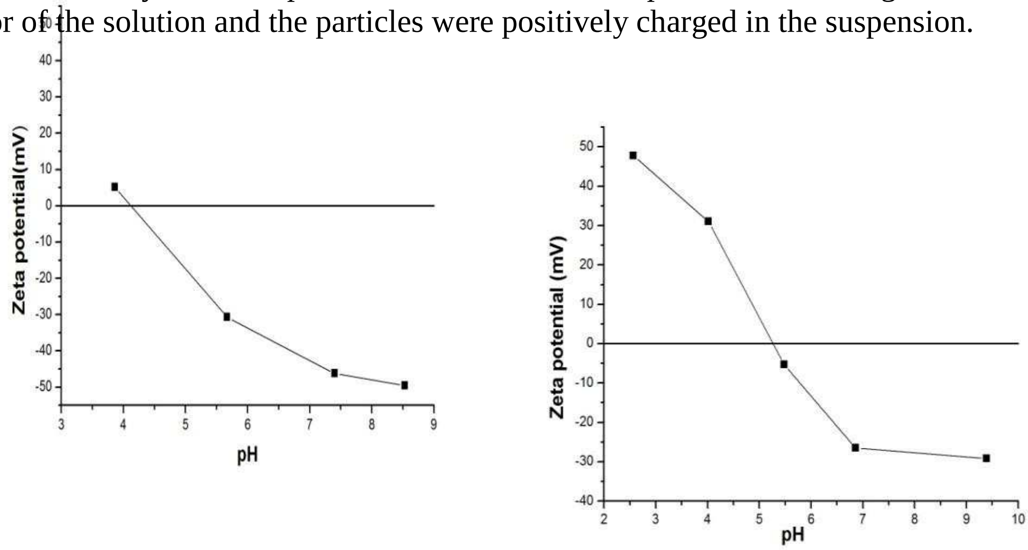


Figure 4.2: *pH* Vs Zeta potential for iso electric point determination of (a) TiO_2 (b) Al_2O_3 powder in water

5. Conclusion

In the present study, Cu-TiO2 and Cu-Al2O3 nanocomposite coatings were developed successfully by using Electrodeposition process on the Copper substrate from copper sulfate bath. From the detailed investigation of the results obtained, the following conclusions can be drawn:

1. The particle size and zeta potential of TiO_2 and Al_2O_3 were determined by using Zetasizer and the particle size obtained was ~202 nm and ~287 nm respectively. And the iso electric points were around 4.2 *pH* for TiO_2 and around 5.3 *pH* for Al_2O_3.

2. From the XRD patterns, Tetragonal and Rhombohedra crystal structures of TiO_2 and Al_2O_3 respectively were confirmed. The XRD peaks of both powders does not show appreciable peak broadening though the sizes of both particles are in nanometric size, as the powder were synthesized by a chemical route which does not introduced strain into the material. The XRD pattern of Cu-TiO_2 and Cu-Al_2O_3 coatings does not show TiO_2 and Al_2O_3 peaks clearly with much intensity because of less wt% (less than 10%) of powders embedded in the composite coatings. The Cu-Al_2O_3 XRD pattern also showing the peaks of Copper Oxide (Cu_2O, JCPDS Reference No: 05-0667) with very less intensity.

3. From the Texture calculations of Cu a strong (220) texture was obtained for composite coatings and pure copper depositions, the intensity of (220) texture and shift of this texture plane to mixed plane orientations was obtained due to the particle incorporation, the current density and Cu_2O in Cu-Al_2O_3. At 8, 11 A/dm^2 current density, 10 and 30 g/l Al_2O_3 in the bath along with (220) texture (311) preferred plane is also observed. Whereas a (111) texture was observed for substrate (pure copper). The crystallite size was calculated by using Scherrer formula from (111) peak and was below 100 nm for all the coated samples.

4. The microhardness values obtained for both the composite coatings are higher than the pure copper hardness, the improvement is attributed to dispersion strengthening caused by the embedded second phase particles, texture and modified microstructure of copper matrix. For Titania, there is maximum of 1.28 and 2.46 times increase, for Alumina there was maximum of 2.07 and 2.6 times increase in microhardness after addition of dispersion with respect to substrate and pure copper deposition respectively was observed.

7. Future Scope

Due to the unstable data, results of Electrical resistivity measurement could not be reported. It is one of the important future works that can be carried out to justify the application of these coatings to electrical components.

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