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# A Fine Atomization CMP Slurry for Copper

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**Abstract.** In this paper, a kind of alkaline slurry was introduced, in which silica was used as the abrasive, $H_2O_2$ was used as the oxidize, glycine was used as the complexing agent, azimidobenzene was used as the surfactant, and borax was used as the pH regulator. The atomization polishing method was used, and the effects of the traditional polishing and atomization polishing were compared. After the atomization polishing, the surface roughness of copper was 7.61 nm and the material removal rate was 188 nm/min; After the traditional polishing, the surface roughness was 15.22 nm and the material removal rate was 236 nm/min. The dosage of polishing slurry used in the atomization polishing is dozens of times less than that in the traditional polishing.

## Introduction

Chemical mechanical polishing process (CMP) is the most effective method which is currently used to implement local and global material planarization, and it is widely applied in flattened surface treatment of hard brittle materials and IC process [1-3]. With the stringent requirements of microelectronics devices, IC chips are developing to high density, high integration and high performance. These make the feature size of integrated circuits more and smaller, with the size decreasing from 0.25 μm to 0.13 μm or smaller. The interconnected metal layers of chip are developing to multi-layers [4,5]. These changes will put forward more requirements on the layer planarization of IC process. Copper polishing slurries are the key factors of copper CMP global flattening and they determine the overall polishing crafts good or not.

Alkaline slurry has some advantages, such as little corrosive, high selectivity (forming automatically a layer of oxide film in the copper surfaces to enhance selectivity) etc. Domestic research level has developed a lot, but there is a big gap compared with international famous companies [6]. Therefore, the alkaline slurry study which is suitable for sub-micron and deep submicron process is necessary. In the alkaline slurries, arasive, oxidant, pH regulator and complexing agent are the main components, and they almostly determine material removal rate and surface quality in the CMP process. The method of fine atomization CMP is that the components are atomized with controlling ultrasound frequency to form SMD5-15um uniform droplets, and then it is transported to the polishing interface. They can form uniform film which has low shear strength on the surface of workpiece through the strong adsorption and the high-performance uniform chemistry between interface, and then the film is removed by mechanical function. The method can significantly reduce the dosage of slurry, and it is helpful in getting better workpiece surface quality. Therefore, there is far-reaching significance in researching the polishing slurry which is suitable to fine atomization CMP. This article mainly studied on the preparation sequence of slurry, polishing efficiency and polishing surface quality in order to get good atomizing slurry which is suitable for the IC process.

## CMP Experiment

Composition choice: Slurries affect both chemical and mechanical process of CMP [7]. In order to form a soft and crispy oxidation film in copper surface to improve removal efficiency and flatness, alkaline slurry is introduced. $H_2O_2$ was used as the oxidize in this paper, and white carbon black was used as the abrasive in order to avoid surface damage and $Al^{3+}$ pollution[8]. Glycine was used as complexing agent in alkaline slurry in order to form copper-amine soluble ion, improve the copper removal rate, control the pollution of metal ions and avoid gel phenomenon of slurry. BTA was used as surfactant, and it can guarantee the slurry's dispersion and reduce the formation of corrosion pit in copper surface. In addition, borax was used as pH regulator. Borax in water has great solubility and can make the pH value keep stable at 9.5-10.5. According to the past experiences and the analysis of experimental phenomena, we got a compounding order for stability test. Firstly, pH regulator was put in the beaker, and surfactant was added. Then a certain volume of deionized water was put in to adjust the pH value, silica (particle size is 12nm) was put in with electromagnetic stirring, and complexing agent, oxidants were put in by turns. Finally, deionized water was added into reach predetermined amount. It can get stable slurry with this method.

Polishing technology: UNIPOL-1502 experiment machine was used in the experiments. The rotate speed of polishing pad was 50 r/min; The polishing pressure was 5 psi; Environmental temperature was room temperature; The time of traditional polishing was 5min and the atomization polishing was 9min. Specimens were $\Phi$25 mm×1 mm, and they were wire-cut and burnished copper slices. The material removal rate is measured with electronic balance whose accuracy was 0.01mg, and the removal rate was calculated with the average weight of four times weighing. Surface topography and roughness were watched with atomic force microscopy (CSPM5000).

Through researching and analysising on documentary about the copper alloys CMP and repeating test, we have obtained a low pollution and good effect polishing slurry.

Table 1: Slurry components and main parameters

| Slurry | I | II | III |
|---|---|---|---|
| Abradant material (quality)/wt% | 1 | 1.5 | 3 |
| Oxygenant(hydrogen peroxide) /wt% | 8 | 5 | 5 |
| Surfactant (BTA) /wt% | 1 | 0.5 | 1 |
| Complexant(glycine) /wt% | 1.5 | 1.2 | 0.7 |

## Experimental Results and Discussion

From different kinds of test, we choosed three kinds of slurries to compare their polishing effects, respectively. Slurry I and slurry II were used in the traditional CMP, and slurry III was used in the atomization CMP.

Table 2: polishing effects contrast

| Slurry | I | II | III |
|---|---|---|---|
| Quality changes after polishing $\Delta m$ [g] | $3.95\times10^{-3}$ | $4.54\times10^{-3}$ | $6.50\times10^{-3}$ |
| Removal rate [nm/min] | 205 | 236 | 188 |

Table 2 shows that there is no great difference in removal rate between traditional and atomization CMP, and it was found that the time of atomization CMP was longer than that of the traditional CMP, which is good for the mist fully diffused to achieve ideal removal rate. Different components' adding sequence and their proportions also influenced the removal rate. The surface of workfiece polished with polishing slurry I produced corrosion pit obviously, and it produced many scratches which was polished with polishing slurry II, but the corrosion pit and scratches significantly reduced after polishing with slurry III. After the experiment, the consumption dosage of polishing slurry III was dozens of times less than that of the slurry I and II.

The surface morphology of workfieces were observed by AFM (Fig. 1-3).

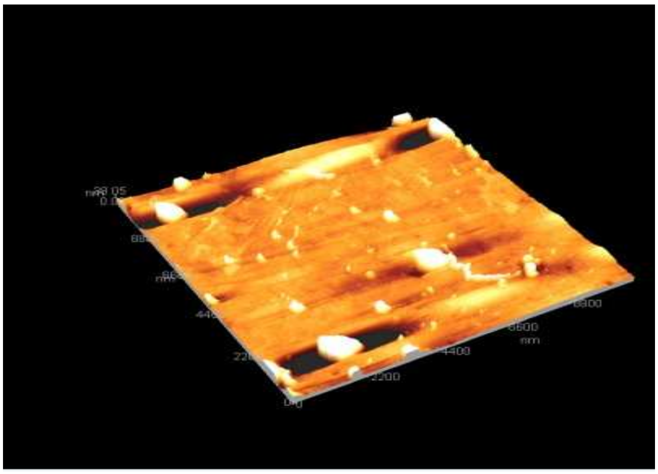

Fig. 1: The surface morphology of copper after polished with the slurry I

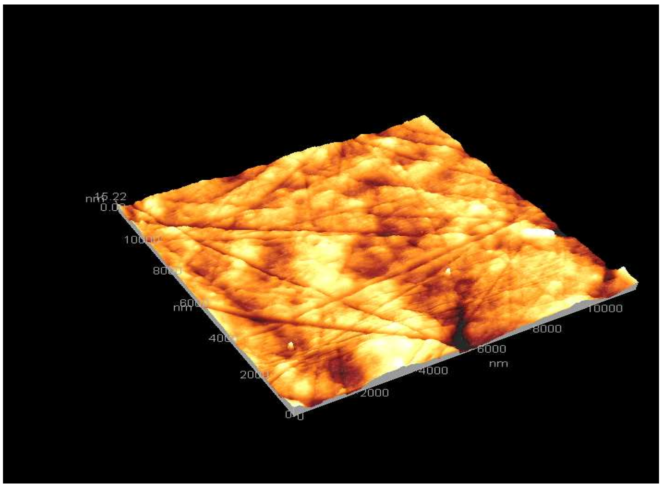

Fig. 2: The surface morphology of copper after polished with the slurryII

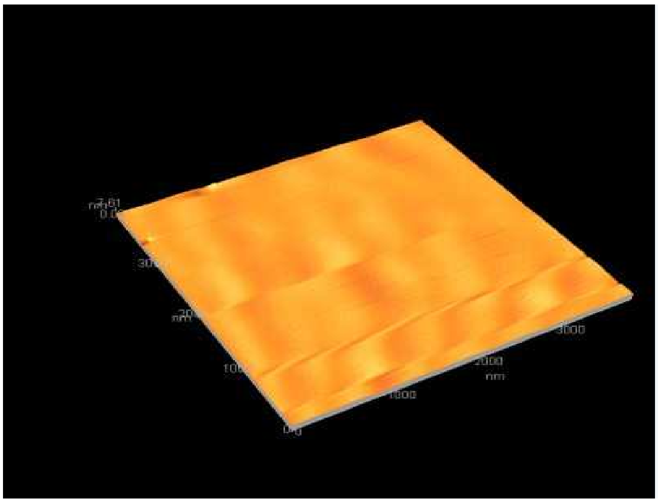

Fig. 3: The surface morphology of copperafter polished with the slurry III

Both the traditional CMP or the atomization CMP method can obtain higher surface planeness of the copper. However, the traditional CMP method causes the imbalance of chemical and mechanical action easily, such as surface pollution, scratches and corrosion etc. After the experiments, slurry I reduced the surface roughness of copper significantly from 50nm to 38.05 nm, slurre II reduced the surface roughness of copper from 25 nm to 15.22 nm, and slurry III used in the atomization CMP reduced the surface roughness of copper from 12nm to 7.61 nm. It is obvious that CMP with the atomization slurry can not only greatly reduce the consumption of slurry, but also achieve better surface quality of workpiece.

## Conclusion

From the experimental results can be found:

a) The prepared polishing slurry III is applicable to fine atomization CMP, and it has no excitant odour and has good stability to satisfy the requirements of copper CMP. The material removal rate is 188 nm/min and the surface roughness of copper reach 7.61 nm.

b) The consumption dosage of polishing slurry in atomization CMP is dozens of times less than that in the traditional polishing.

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