Effect of Pad Hardness on Planarization Efficiency of Selected Features in Cu CMP

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Abstract: The planarization efficiency of Cu bulk polishing was determined for four pads of which hardness (Shore D from 59 to 23) was the only variable. Three groups of features were monitored to follow changes in dishing on isolated lines (100, 50, 10, and 5 μm), protrusion on fine line arrays (line/space of 1/1, 0.5/0.5, 0.25/0.25, and 0.18/0.18 μm), and erosion on different densities (50/1, 9/1, 5/1, and 3/1 μm) as a function of Cu thickness. The results show that planarization efficiency of various patterned features was influenced strongly by pad hardness and that pad was the key factor in delivering planarization. Above Shore D 47, pad hardness had a small effect on planarization efficiency. Below Shore D 47, planarization efficiency decreased dramatically with decreasing pad hardness. Improvement in planarization efficiency by slurry formulation was much smaller compared to the effect of pad hardness in most cases, but might be significant for some features on a pad of medium hardness (e.g. dishing on 10 and 5 μm lines on D34 pad).

Introduction

Planarity of wafer surface as measured by residual step height continues to be the key deliverable in chemical and mechanical planarization (CMP) for Cu bulk removal. A hard pad is typically used to achieve good planarization efficiency but it can be a concern for mechanical defects. In contrast, a softer pad can be used to reduce mechanical defects but planarization efficiency is usually compromised. We have reported the effect of pad hardness on planarization efficiency of Cu protrusion [1], but the pads used in the previous study had different characteristics and a simple correlation with pad hardness value could not be made. In present study, four pads of same design were used, making it possible to determine the effect of pad hardness on planarization efficiency.

Experiment

The four pads used in this study were provided by NexPlanar. They were manufactured using the same materials and had the same groove patterns and thickness. Therefore, pad hardness was the only major variable. As shown in Table 1, the hardness in Shore D scale was from 59 to 23 and covered the range from hard pad to soft pad. Two colloidal silica slurries were tested: a commercial PLANERLITE 7106 (PL7106) and a developmental Slurry D which was previously developed to improve planarization efficiency of Cu protrusion [1]. All polishing tests were carried out using commercial 200 mm patterned test wafers (of 854 mask) on an IPEC Westech 372M polisher. A 3M A165 pad conditioner was used for D59, D47, and D34 pads whereas a 3M A3700 conditioner was used for D23 pad. The following polishing process conditions were used: head/platen rotational speed, 85/80 rpm; pressure, 1.5 psi; and slurry flow rate, 200 mL/min. The step height was measured on a KLA-Tencor HRP350 profilometer.

Table 1. NexPlanar pads used in this study

Pad #1	Shore D 59	Hard pad
Pad #2	Shore D 47	↓
Pad #3	Shore D 34	
Pad #4	Shore D 23	Soft pad

Results and Discussion

Figure 1 shows the effects of pad hardness on step height reduction for various features based on polishing by PL7106. When pad hardness decreased, planarization efficiency decreased only slightly from D59 to D47 but dramatically from D47 to D23. For dishing on isolated lines, final step height (after removing 6000-7000 Å of Cu) decreased with decreasing line width. Zero dishing was attained for 5 and 10 μm lines on D47 and D59 pads but not on the softer D34 and D23 pads. The 50 and 100 µm lines did not reach zero dishing on any pad. In comparison, erosion in the arrays (with a width of ~1250 µm) was more difficult to planarize. For protrusion over fine line arrays, <100 Å final topography was obtained on D59 and D47 pads, but not on the softer D34 and D23 pads.

Figure 2 shows improvement in planarization efficiency by slurry formulation for selected features. On D59 and D47 pads, dishing on 10 µm and protrusion on 0.18/0.18 µm was reduced to zero or near zero by using PL7106 and little or no improvement was obtained by using Slurry D. On D34 pad, the improvement was noticeable and could be significant for some features as discussed later. On the softest D23 pad, the improvement was small and far from enough to help reduce step heights to an acceptable level. For erosion at 5/1 µm, the improvement by slurry formulation was inconsistent on D59 and D47 pads but noticeable and consistent on D34 and D23 pads.

Figure 3 compares the effects of pad hardness and slurry formulation on residual step height for selected features. (The residual step height when 5000 Å of Cu remained after removal of 6000 Å of Cu was estimated by linear interpolation between two data points.) Above D47, only a small benefit was gained by using a harder pad. Below D47, however, the effect of pad hardness was very strong and planarization efficiency decreased dramatically when a softer pad was used.

By comparison, improvement in planarization efficiency by slurry formulation was much smaller than the effect of pad hardness. Thus, pad hardness was the key factor that determined the planarization efficiency. However, the improvement by slurry formulation could be significant for some features on a pad of medium hardness. For examples, on D34 pad, the residual dishing was reduced from 200 Å to ~0 Å on 5 µm line and from 635 Å to 250 Å on 10 µm line (a 60% reduction, shown in Figure 3) by changing from PL7106 to Slurry D.

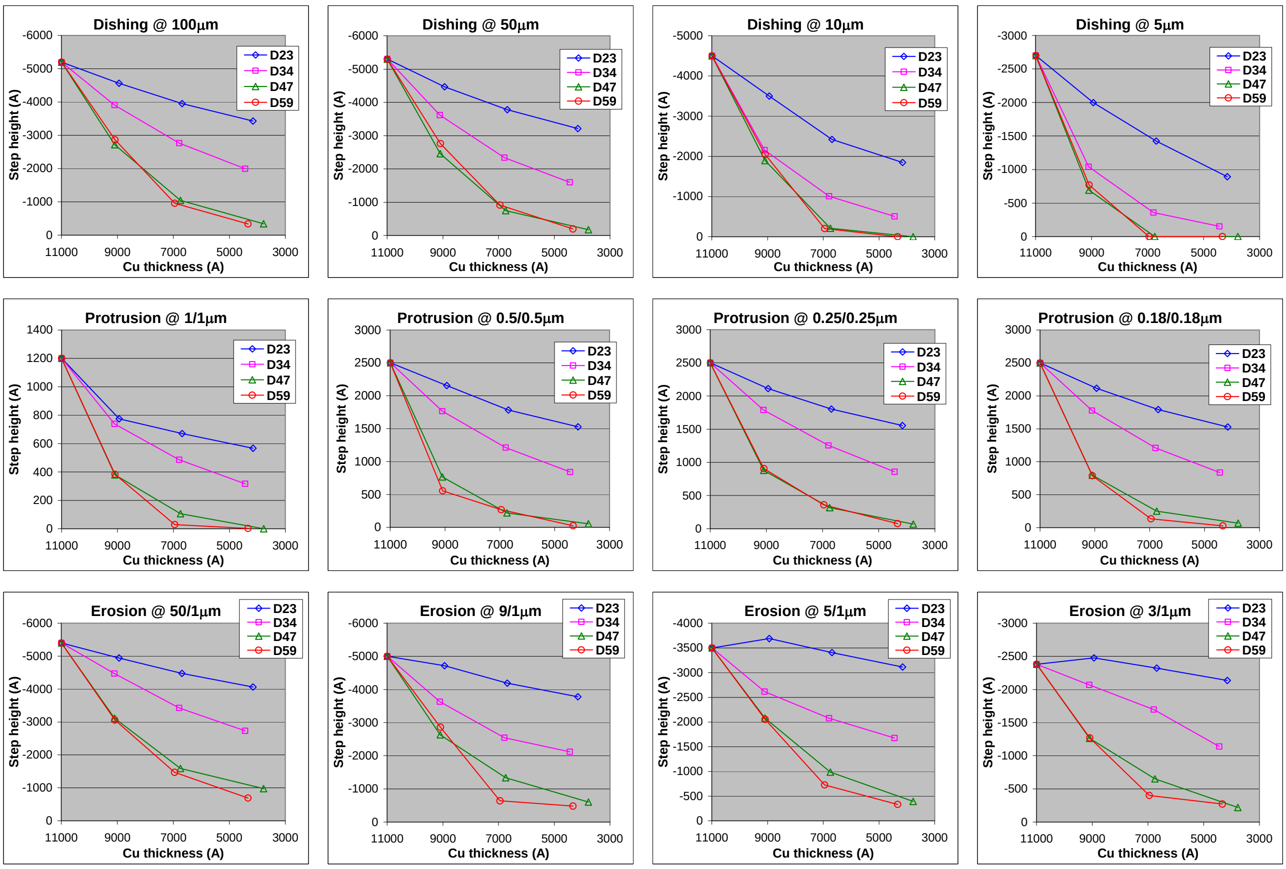

Figure 1. Effect of pad hardness on planarization efficiency by PL7106 for various features.

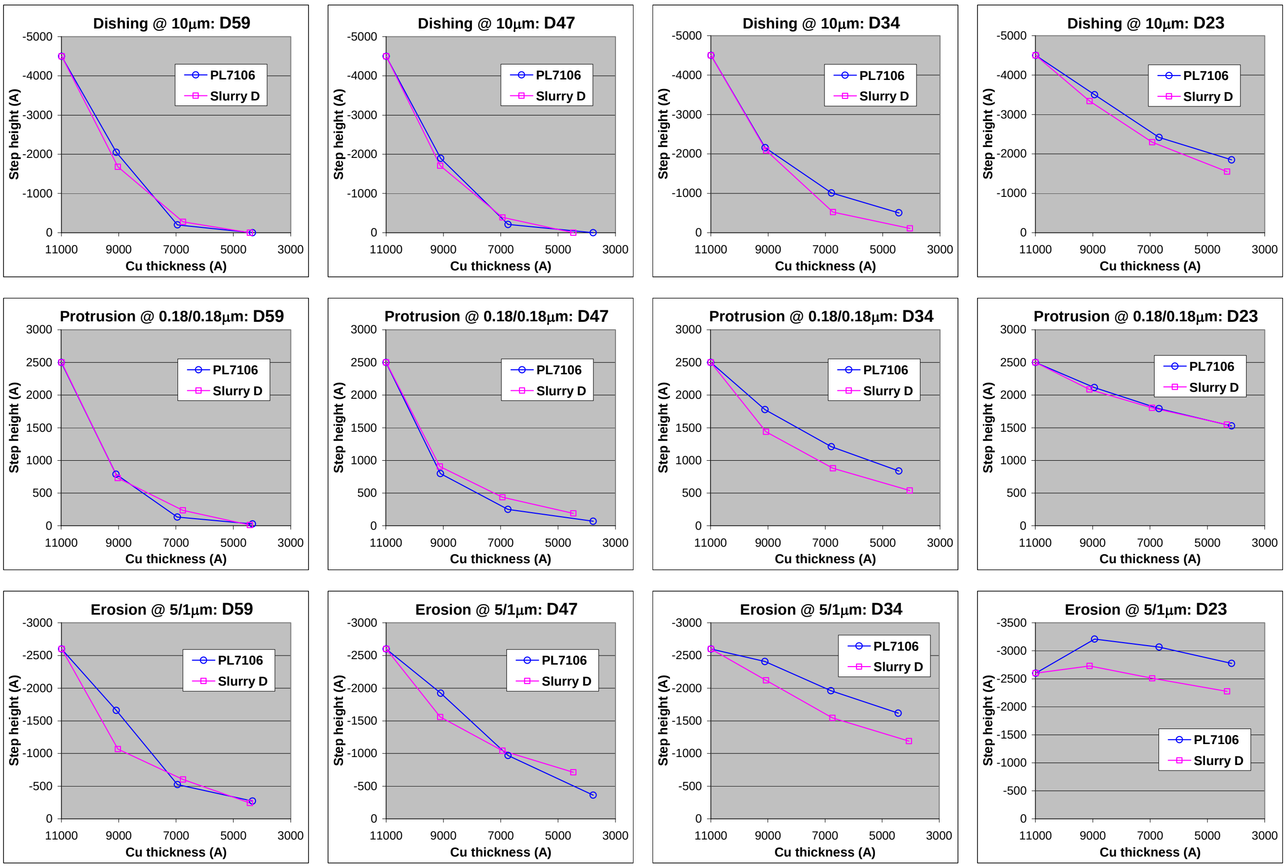

Figure 2. Improvement in planarization efficiency by slurry formulation for selected features.

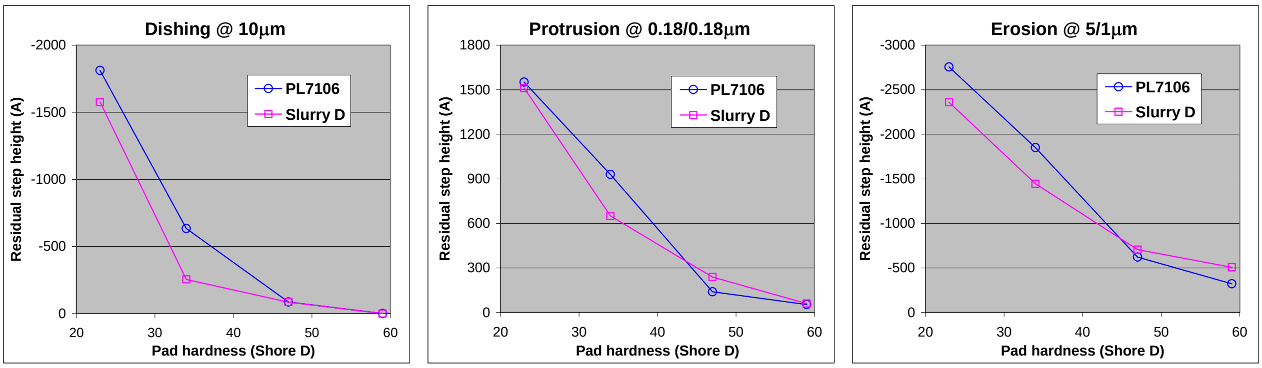

Figure 3. Effect of pad hardness and slurry formulation on residual step height (5000Å Cu remained/6000Å Cu removed).

Summary

Four pads with hardness in the range of Shore D 59 to 23 were studied for planarization efficiency in Cu bulk polishing. The results show that the effect of pad hardness on planarization efficiency is very strong when pad hardness is below Shore D 47. Improvement in planarization efficiency by slurry formulation is much smaller compared to the effect of pad hardness but can be significant for selected features on a pad of medium hardness. Overall, pad hardness is the key factor in delivering planarization in Cu bulk polishing.

Keywords

Chemical mechanical planarization (CMP); pad hardness; step height; planarization efficiency.

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References

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