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A Study of Nanoparticle Removal on Patterned Surfaces

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Introduction: It is believed that nanoparticulate contamination can affect device yield. Therefore conventional and advanced cleaning solutions have been used and proposed to remove detrimental particles and other contaminants since the beginning of the semiconductor industry. Nowadays most cleaning methods use an additional physical force. Therefore not only the evaluation of particle removal efficiency but also evaluation of any possible generated damage to micro- or nanostructures is required. Nanoparticle removal efficiency of various cleaning techniques is commonly assessed on *blanket* substrates and only few examples exist on *patterned* wafer substrates [1-3]. However most cleaning steps are done on patterned substrates and are thus aiming at removing killing particles in between patterned lines.

In this paper a novel method is presented whereby both the damage and the particle removal rate on one patterned substrate can be assessed. There are multiple advantages for this method over the common method: 1) the two separate tests for PRE and damage can be replaced by one 2) non-uniformities in both particle removal and damage generation can be compared locally and 3) the presence of structures between particles will alter the removal mechanisms reflecting a real case cleaning scenario. The latter is believed being the biggest benefit of this method. In this paper this novel method will be introduced to evaluate a representative and common cleaning technique: aerosol spray cleaning. We intentionally used spray conditions that generated *some* damage in order to evaluate this method.

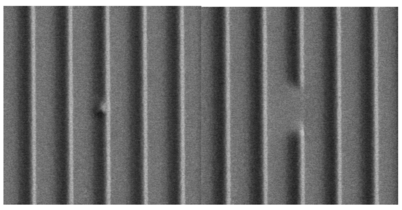

Figure 1: SEM images of a 78 nm deposited silica particle on a patterned wafer (left) and a typical line interruption due to the impact of physical forces (right image).

Method: To evaluate this novel method against the common method, three sets of wafers were used: 1st set) two contaminated patterned wafers with 78 nm silica particles by spin-on; 2nd set) two non-contaminated patterned wafers; 3rd set) two blanket silicon wafers contaminated with 78 nm silica particles by spin-on. The 3 sets of wafers were cleaned on a spray cleaning tool using a recipe based on either UPW or APM. The 1st and the 2nd set of wafers were measured using a brightfield inspection tool (KLA2835) before and after controlled contamination if applicable and after clean. The particles could be differentiated from the damage by automatic classification on the KLA 2835 based on polarity: dark polarity defects are typically particles and bright polarity defects are missing lines due to damage events (figure 1).

Results & Discussion: After controlled contamination of the patterned wafers (1st set) a high defect count was recorded by the brightfield inspection tool. These defects represent the deposited particles as confirmed by SEM (figure 1). In a subsequent step a relatively aggressive spray clean was applied on this set of wafers. The wafer defectivity level for the different steps is shown in figure 2. Two different cleans were assessed: one using UPW and one using APM. These two chemistries were selected to have a clear difference in cleaning performance in order to benchmark our method. After cleaning, the defectivity level significantly decreased: a clear indication of particle removal. The 2nd set of wafers (non-contaminated patterned wafers) showed an increase in the total number of defects after clean (not shown here). These added defects could be attributed to damage due to the use of a high velocity aerosol spray condition . By applying *defect source analysis* (DSA), we could trace back that *also* the 1st set of wafers had a number of added defects attributed to damage due to the use of this spray condition (figure 2). After having differentiated the defects due to damage from the particle-defects we could calculate both the damage and the particle removal rate. The UPW clean had 46% of the particles removed and the APM clean 77% of the particles removed. The APM clean on the other hand generated more damage. These trends in the results are along the expectations and are a proof of concept for this new method.

The particle removal efficiencies on the reference blanket wafers (3rd set) using identical spray cleaning processes were remarkably higher: 94% for UPW clean and 99% for the APM clean. These values are much higher than those on patterned wafers and clearly demonstrate that the nanopatterns affect particle removal. It is believed that the patterns hinder the drag force exerted by the spray to act on the particles. These results illustrate how important it is to relativize particle removal efficiency results obtained on blanket wafers.

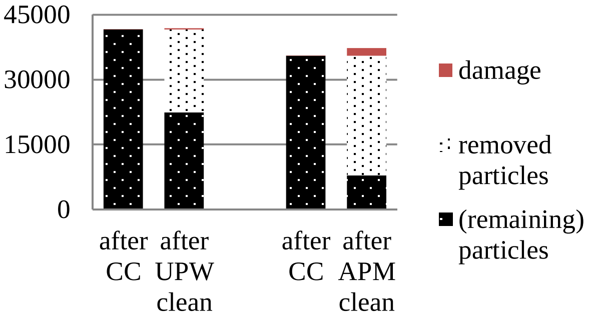

Figure 2: defect-count for the patterned wafers after controlled contamination (CC) and after clean. The defects observed after clean were remaining particles and damage. The cleaned particles are merely shown as an illustration.

Conclusion: The presented test method will make it easier to compare and benchmark a variety of cleaning methods. This method is applicable for wet cleaning methods like aerosol cleaning, megasonic cleaning as well as for dry cleaning methods like laser ablation, laser shock wave and cryogenic aerosol cleaning. This method allows better understanding of the particle removal mechanism and on how nanostructures can affect nanoparticle removal.

[1] Shangjiong Y. et al., Langmuir, 2011, 27 (18), p.11430–11435
[2] Bakhtari K. et al., Journal of the Electrochemical Society, 153 (9) C603-C607 (2006)
[3] Wostyn K. et al., Solid State Phenomena Vol. 134 (2008) p.221-224