Influence of Circuit Geometry, Edges and Roughness on Liquid Penetration and Removal during Wet Cleaning

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Surface preparation and cleaning of silicon wafers using wet chemicals is one of the most ubiquitous processes in the manufacturing of integrated surfaces. As the industry follows Moore's Law, more circuits of greater complexity are being packed into the tighter spaces. In order to clean smaller, more intricate trenches and vias, manufacturers must be able to effectively wet them. In this work, using both experiments and modeling, we examined the how edges and roughness influence the penetration and removal of wet cleaning liquids from model trenches and vias.

First, we demonstrate through experiments how edges affect the advance of liquids and their contact angles. For example, consider the model feature shown schematically in Figure 1, in this case a truncated cone. A small drop of water is deposited atop the feature and liquid is sequentially added. If the contact diameter of the drop is less than the diameter of the feature, then the drop exhibits an inherent advancing contact angle. As more water is added, the contact line advances to the feature edge and is pinned. With the addition of yet more water, the contact angle increases and the drop eventually establishes its inherent advancing contact angle on the side of the feature. At this critical juncture, the water flows down the side of the feature. This ability to impede movement of liquids across rough surfaces was first described by Gibbs[1] and has been experimentally verified by others[2, 3].

Next, by incorporating the Gibbs relation into models for liquid penetration and retention, we estimated the forces and pressures required to move liquids in and out of rough trenches and vias during cleaning. We show that both feature geometry and roughness can dramatically increase the resistance to penetration and/or removal of liquids from trenches or vias. For instance, roughness can turn a trench that is easily wet by a cleaning chemistry into a trench that repels the same liquid, as depicted in Figure 2. Alternatively, roughness can greatly enhance the retention of liquids embedded in trenches or vias, Figure 3.

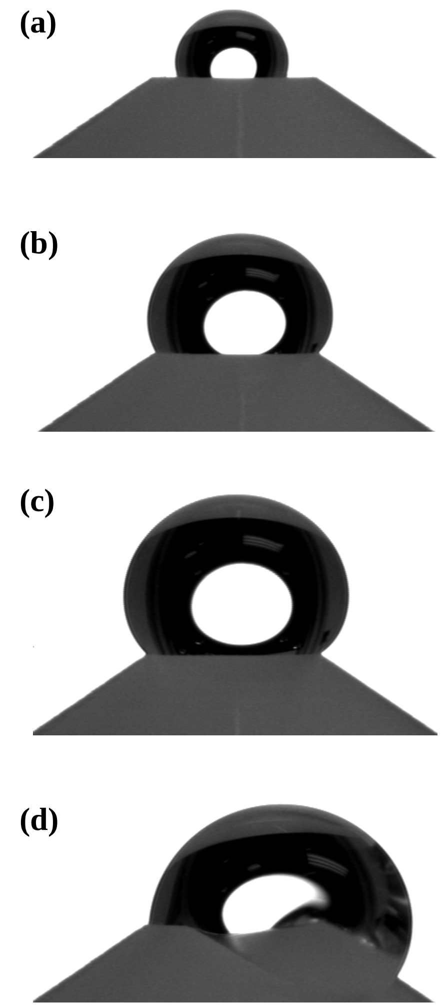

Figure 1. Sequential addition of liquid to the top of a feature. (a) A small drop of water is deposited on a smooth, truncated cone. (b) As water is added, the contact line advances to the feature edge and is pinned. (c) Addition of more water causes the apparent contact angle to increase. (d) With yet more water, the drop its intrinsic advancing contact angle on the side of the feature and then collapses.

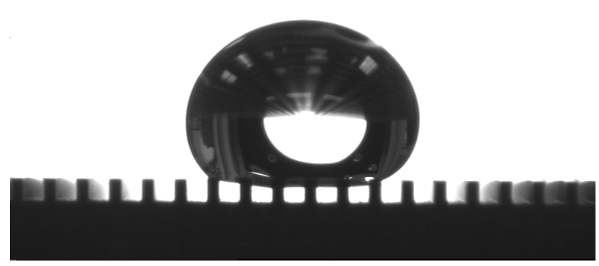

Figure 2. Water repelled from entering trenches.

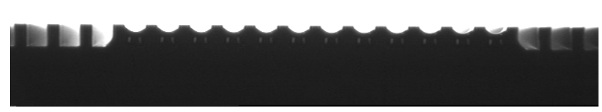

Figure 3. Water retained inside of trenches.

References

1. Gibbs, J. W., On the Equilibrium of Heterogeneous Substances. In *The Collected Works of J. Willard Gibbs*, Yale University Press: New Haven, 1961; Vol. 1, pp 326-327.
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3. Extrand, C. W., Modeling of Ultralyophobicity: Suspension of Liquid Drops by a Single Asperity. *Langmuir* **2005,** 21, (23), 10370 -10374.