# Conformal and superconformal film deposition by CVD: a tutorial on smart surface chemistry

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Several key steps in the fabrication of microelectronic circuits, such as the creation of vertical wires and capacitors, involve the coating or filling of a recessed feature. In current microelectronic fabrication processes, physicial vapor deposition (PVD) methods such as magnetron sputtering are commonly employed to fill such recessed features. Although PVD works well to fill features with aspect ratios (depth/width) smaller than about 10:1, attempts to use it for features with larger aspect ratios invariably lead to a phenomenon called "pinch off": the opening becomes plugged, with formation of a large void underneath (Fig. 1). This effect arises because PVD is a "line of sight" technique: the sputtered atoms that constitute the deposition flux tend to stick to the first surface they encounter.

Pinch-off is the result of *sub-conformal* deposition: growth is fastest at or near the surface and slower inside the recessed feature. As microelectronic devices become increasingly miniaturized, however, and recessed features necessarily take on larger aspect ratios, there is an increasing need to deposit films *conformally* (equal growth rate everywhere) or even *superconformally* (fastest growth deep inside a feature).

Atomic layer deposition (ALD) is able to deposit conformal films in deep vias and trenches. In ALD, two (or more) individual CVD precursors are passed over the substrate one at a time, separated by a purge step. Precursor chemistries and process conditions are chosen such that, during each exposure step, precursor molecules react with the surface until all available surface sites are saturated (or until steric hindrance dominates), at which point no further reaction takes place. This self-limited attribute leads to highly conformal growth. Although ALD is a great technique, it becomes very slow as aspect ratios increase, owing to the need for the ALD growth species to diffuse into and then out of the feature in each step. As a result, the rate at which ALD films can be deposited slows with the *square* of the aspect ratio.

In this tutorial, we will describe our efforts over the last few years to develop new kinds of chemical vapor deposition (CVD) methods that are able to deposit films both conformally and superconformally. Because CVD operates continually, it is much faster than ALD in features with high aspect ratios. Our approach has been to think like chemists and to use kinetic concepts such as inhibition, differential diffusion, and rate laws to invent new methods to control film thickness as a function of depth. A variety of specific examples of our new approaches will be illustrated.

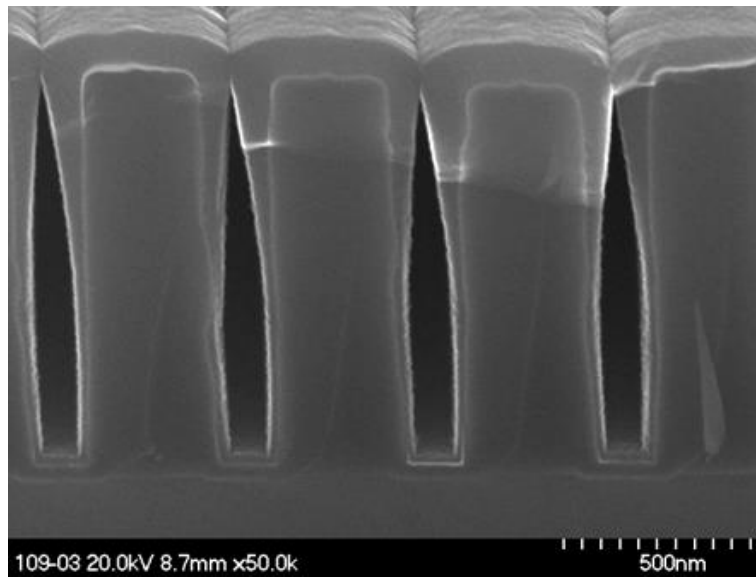


**Figure 1**. Example of pinch-off.