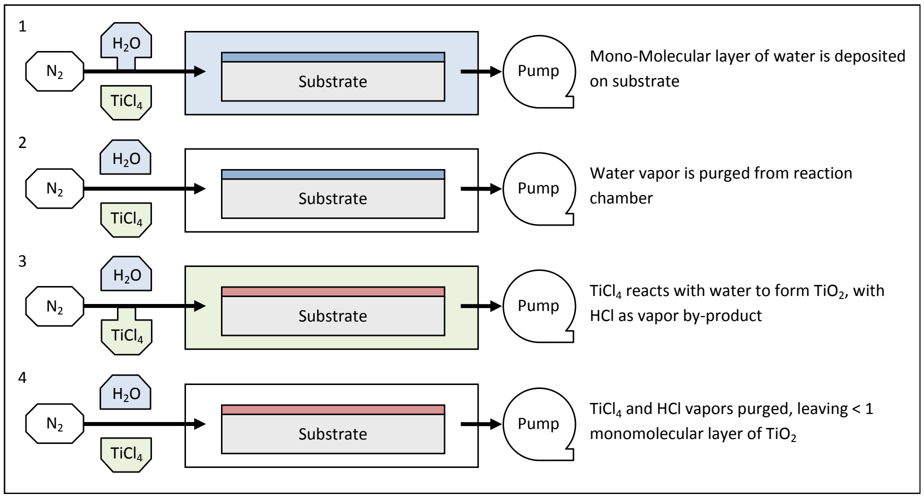
Atomic Layer Deposition (ALD)

ALD is a unique thin film deposition process, capable of depositing very high quality thin films with extreme precision. Similarly to CVD, ALD processing relies on chemical reactions at the substrate surface, usually at elevated temperatures. Unlike CVD, the film is grown one atomic layer at a time, utilizing self-control through saturating surface reactions. This is achieved by separate, sequential exposure to different precursors, one at a time. The first precursor chemisorbs to the surface, saturating the surface with one molecular layer. Next, a second precursor is introduced, which reacts with the single layer of the first precursor to form the desired compound. This reaction stops after the monolayer is reacted, completing what is called an ALD cycle. This cycle sequence is then repeated until the desired film thickness is achieved. Until very recently, virtually all ALD processing was performed using sequential dosing and purging of the precursors from a common volume containing the substrates. An example of a common 4-step ALD cycle sequence used for the deposition of TiO_2 films is illustrated below:

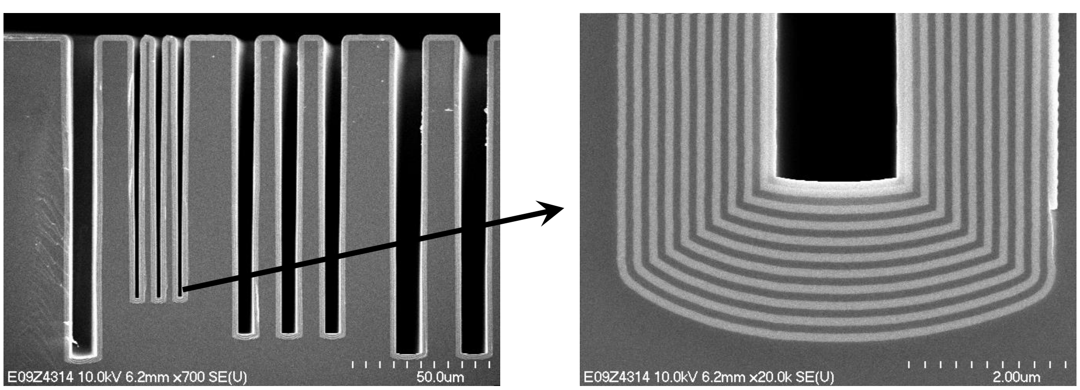


One of these 4-step cycles generates a completed TiO_2 layer which is approximately 0.1 nm thick. For thicker films, the cycle is repeated until the desired total thickness is attained.

Attributes

The outstanding physical and electrical properties of ALD films, compared with sputtered, evaporated and CVD films are well documented, and include the following characteristics:

- Extreme coating conformality – This attribute allows for uniform coating of rough and irregular surfaces as illustrated in the following images of a deep, narrow trench in silicon, coated with alternating layers of ALD Al_2O_3 and Ta_2O_5:



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- High film density with low film stress – ALD processes generally produce films with no intrinsic stress as deposited, even though film density is generally very high compared with conventional PVD and CVD films.

- Truly pinhole-free coatings – The conformality and saturation characteristics of the ALD process lead to a unique capability to produce thin films without pinholes, even on surfaces with scratches and other mechanical defects. Even when particles are present on a substrate surface, these characteristics provide for coating underneath loosely adhered particles, and fully encapsulating tightly bound particles.

- Robust, uniform, continuous films even when extremely thin – The saturation characteristic of the process provides excellent characteristics for very thin films. In the semiconductor industry ALD films as thin as two to three nanometers have been investigated and deployed as dielectrics and metal diffusion barrier films.

- Greatly simplified equipment requirements and process control – ALD is typically done under medium vacuum, with no high vacuum pumps required. It also does not require source assemblies, such as cooled crucibles for evaporation or cooled targets for sputtering processes. And unlike any other thin film process, the film growth properties are unrelated to process parameters critical to other deposition methods. As long as precursor saturation and purge are maintained in the cycle, precursor flux, cycle time, minor temperature fluctuations, etc. have little or no effect on film properties, including thickness, uniformity, and physical and electrical properties. Thickness is simply determined by the number of completed cycles, thus no sophisticated monitoring or feedback controls are required.

- Low materials cost – ALD is unique in that the film can *only* be formed through a specific sequence of chemisorption and subsequent reaction. As a result, contaminants present in precursor materials are generally not incorporated into the film, as they cannot participate in this specific reaction sequence. For processes such as Al_2O_3 and TiO_2, very low purity industrial precursor chemicals are routinely used to produce high quality, high purity oxides.

- Limitations of conventional ALD – The most significant single drawback of conventional ALD processing is the extremely low coating rate. Depending on the geometric complexity of the substrate, substrate chamber, temperature, and precursor delivery system, anywhere between a few seconds and a minute may be required to complete one cycle, producing approximately 0.1 nm film thickness. This means that the time required to coat a reasonably thick film of at least 10 to 20 nanometers (100 to 200 cycles) may take anywhere from several minutes to more than an hour. This in turn has lead to a widely held perception that although the quality of ALD films is extremely high, the process is inherently slow and expensive.

ALD by Lotus Applied Technology

Our technology utilizes a different approach to the ALD process, which moves the substrate physically in space between separate precursor zones, rather than sequentially introducing and purging precursors from a common volume. This approach eliminates the time required to introduce and purge the precursor from a common space, dramatically increasing deposition rates, while still providing the excellent film attributes associated with conventional ALD processing. For more information, please visit our website at www.lotusat.com.