How ALD Compares with Other Deposition Techniques

Atomic layer deposition (ALD) is a cyclic process carried out by dividing a conventional chemical vapor deposition (CVD) process into an iterated sequence of self-saturating deposition cycles [1]. Unlike CVD- where the reacting gases are mixed in the process chamber and continuously react to form a film- ALD reacting gases are delivered separately to react with the surface instead of with each other. Each reaction is self-terminating, depositing a single layer at a time, independent of gas flow distribution or gas transport into substrate fearures.

ALD's layer-by-layer growth mechanism leads to several unique film properties. Since gas uniformity does not affect layer growth, highly uniform films are deposited with complete conformality. At each deposition cycle film thickness and properties are metered with robust, atomic-level control.

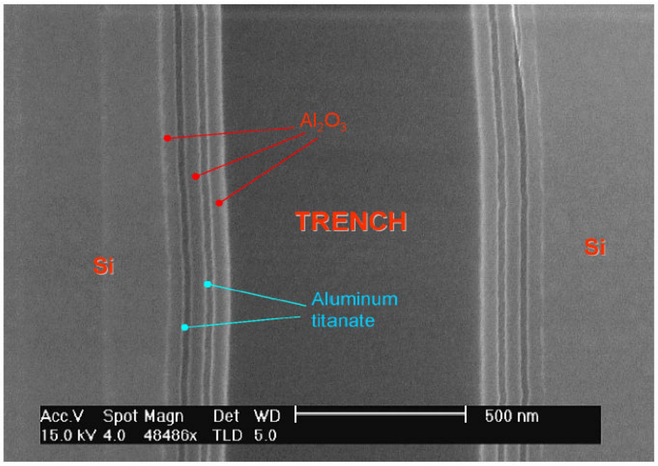
ALD films are uniquely grown without inferior discontinuities caused by nucleation [2]. As a result, ALD films grow pinhole free and practically stress free. All other deposition techniques initiate film growth by nucleation. Nucleation is followed by the growth of grains. When the grains finally coalesce into continuous films the thickness could be on the order of 50-100 Å [3,4] in the case of CVD, and even thicker in the case of physical vapor deposition (PVD).

Films initiated by nucleation exhibit substantial compressive stress and abundance of pinholes that extend far beyond coalescence depth. Pinholes and compressive stress are associated with non-ideal grain boundaries and typically render CVD and PVD films inadequate for passivation and encapsulation applications at layer thicknesses of less than 5000 Å. In contrast, Very thin encapsulation films can be realized by ALD with minimized adverse impact on device performance. For example, IC devices can be encapsulated at the wafer level with minimized impact on performance or subsequent packaging process flow.

The table below compares some of the above ALD film properties to the properties of traditional CVD and PVD techniques.

Property	**ALD**	**CVD, PVD**
Growth Mode	Stepwise- layer by layer	Continuous
Growth Rate	Growth per cycle is accurately defined	Variable
Thickness Control	Dialed in # of cycles	Rate X Time
Film Conformality	Independent of transport	Limited, transport -dependant
Growth Initiation	Continuous film	Nucleation, grain growth
Film Properties	Pinhole-free, negligible stress	Pinholes, compressive stress

The robust sub-monolayer control of ALD enables reproducible deposition of film composites by alternating layer composition at each cycle. Nano-laminate and alloys can be tailored to optimize device performance. An example is shown in the SEM image below.



A stack of alternating Alumina/Aluminum-titanate layers grown into a 350 μm deep by 1 μm wide porous Si membrane. Courtesy of LakeShore Crytoronics, Inc.

This Film engineering capability also allows for film growth in situations where film and substrate properties are incompatible. The incompatibility can be overcome by providing an ultrathin (several monolayers only) interface layer that is compatible with both the substrate and the film. Typically, an interfacing layer of several hundreds of Angstrons is necessary with other deposition techniques.

References

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