TECHtips

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Electronics Manufacturing Insights from ACI Technologies, Inc.

# Atomic Layer Deposition

Is it possible to coat electronic assemblies with a thin, uniform in thickness, pinhole-free, moisture impervious, truly hermetic (by the MIL-STD-883 definition) film of ceramic material that is far more affordable than placing the same electronic assemblies in the currently used glass-to-metal sealed, thick, heavy, metal-and-ceramic-based hermetic enclosures? Since the coating (called a "conformal coating") would be both hermetic (moisture proof) and hundreds or thousands of times thinner than the currently used enclosures, it would be both less expensive, lighter, and still just as effective in excluding moisture (hermetic) as the current heavy, bulky, expensive electronic enclosures are.

Such a coating might indeed be possible.

Atomic Layer Deposition (ALD) is a vacuum-based process of depositing a very pure, well-controlled-composition chemical compound film on a surface, one "atomic layer" at a time. One single "atomic layer" (actually a molecular layer) of reactant products is deposited by controlling the presentation of a single reactant (usually a gas) to the initially bare surface. The deposition stops when all of the reaction sites on the surface are reacted, giving one "atomic layer" per deposition cycle. All of the remaining reactants are completely flushed and removed from the deposition chamber so that only one layer of reaction product molecules can be deposited in each deposition cycle. No further reaction is possible until a different reactant is introduced into the deposition chamber.

Figure 1-1 shows a typical ALD cycle for deposition of Alumina ($Al_2O_3$) ceramic on an aluminum starting surface. The five-step cycle shown is continuously repeated once for each "atomic layer" of $Al_2O_3$. Tri-methyl aluminum is the first reactant gas introduced and water vapor is the second, resulting in one "atomic layer" of $Al_2O_3$ per cycle.

The ALD process is so attractive due to its ability to uniformly coat drastically non-uniform surface geometries. By introducing only one reactant at a time, the ALD process is self-limiting, allowing the reaction to create only one layer of deposited film material by using all the reactive sites on the starting surface. No further reaction can take place because there are no reactive sites left and only one reactant gas is present. Once the reaction chamber is flushed clean of the first reactant, the second reactant is introduced into the chamber, and in turn reacts with the surface until all reactive sites are used. This process cycle is then repeated, depositing one layer of reaction film product per cycle. Because of its inability to deposit any more or less than one molecular layer of reaction product per cycle, ALD cannot deposit excess or insufficient film product at non-uniformities (corners, edges, or holes) in the geometry of the object being coated.

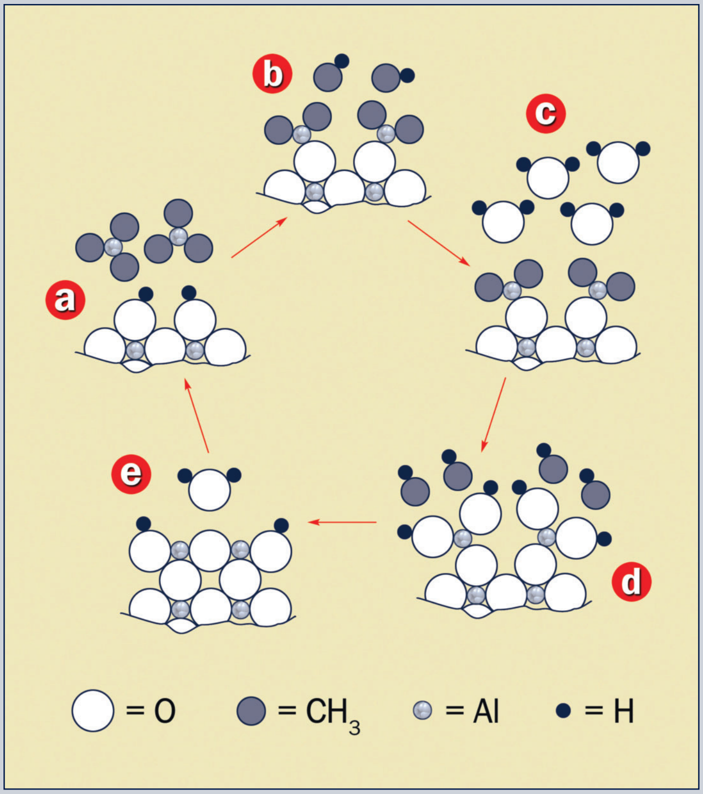


*Figure 1-1: Five-step cycle (a through e) to produce one monolayer of Alumina ceramic ($Al_2O_3$) on a surface. Image courtesy of Sundew Technologies LLC.*

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For instance, it is very difficult to electroplate a uniform thickness of copper in the middle of a plated through-hole with an aspect ratio of 10:1 (printed wiring board thickness to hole diameter). Because of its self-limiting effect, aspect ratios of 1000:1 can be ALD coated with precise film uniformity. This is especially useful in coating complex geometries on Integrated Circuit (IC) chips, such as “air bridge” structures on Monolithic Microwave Integrated Circuits (MMIC) for Radio Frequency (RF) applications.

The unique ability of ALD to provide a uniform coat of very thin ceramic, organic, or metal films onto very non-uniform geometries is put to good use in many critical applications. The excessive build-up of reactant product at edges, steps, and other surface discontinuities common for many other liquid dip, spray, chemical vapor deposition, or electroplated deposition techniques, can be avoided by using ALD as the coating process. This is especially important in RF applications where excess coating can degrade RF electrical performance. The more uniform ALD coating can provide a better electrical performance.

Typically, ALD coatings will be deposited in several hundreds or thousands of cycles, one reactant gas in the chamber at a time, and one layer of reaction product per cycle. A common application might deposit 1000 monolayers of a compound in 45 minutes and 1000 cycles.

Since ALD coatings are often ceramic materials, the possibility exists to obtain a truly hermetic seal on coated electronic assemblies. Formerly, this hermetic seal could only be obtained by enclosing the electronics in a heavy, bulky, glass-and-metal lidded hermetic cavity enclosure. ALD coating may provide an equivalent hermetic seal with a lighter and less costly process.

Finally, a ceramic ALD coating could mitigate tin whisker growth when applied to lead (Pb)-free electronic assemblies having pure tin plated components. ACI Technologies continues to investigate this coating alternative. Could ALD be the solution for your next project? Contact ACI for more information by phone at 610.362.1320, or via email to helpline@aciusa.org or visit us on the web at www.aciusa.org.

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