

INTERNATIONAL STANDARD

**ISO
8181**

First edition
2023-10

Atomic layer deposition — Vocabulary

Dépôt de couches atomiques — Vocabulaire

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Reference number
ISO 8181:2023(E)

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Published in Switzerland

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Foreword

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Introduction

Atomic layer deposition (ALD) is a thin film deposition technique based on the sequential and self-limiting surface reactions of gas phase precursors on substrate. ALD is able to meet the needs for precise thickness control by changing the deposition cycles. ALD films are uniform and remain extremely conformal to the original substrate since the chemical adsorption and reaction of precursors on substrate is self-limiting during each ALD cycle. ALD can also be extendible to large substrates, flexible substrates and large amounts of micro-nano particles. Therefore, the applications of ALD have covered microelectronics, photovoltaics and displays, as well as many emerging fields, including renewable energy, catalysis and biomedicine.

The aim of this document is to provide the systematic terminologies about ALD technique. This enables global professional communications in both industry and academia.

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Atomic layer deposition — Vocabulary

1 Scope

This document defines general terms and film growth processes for atomic layer deposition (ALD). ALD technique is classified into conventional time separated ALD and spatial ALD according to the separation between sequential surface reactions of precursors on substrate. Besides planar substrate, ALD can be used for coating on micro-nano particles, which is developed as powder ALD. Some energy enhanced ALD techniques are also included. This document specifies the processes of different ALD methods.

This document applies to the process of ALD. This document does not apply to the deposited materials or specific nanostructures.

This document applies to industrial production, scientific research, teaching, publishing and scientific and technological communications related to ALD.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

atomic layer deposition

process of fabricating uniform and conformal films through the cyclic deposition of material by alternate self-saturating surface absorption and chemical reactions that enable thickness control at the atomic scale

Note 1 to entry: This process often involves the use of at least two sequential reactions to complete a cycle that can be repeated several times to establish a desired thickness.

[SOURCE: ISO/TS 80004-8:2020, 8.2.2, modified — "through self-terminating surface reactions" has been replaced by "by alternate self-saturating surface absorption and chemical reactions" in the definition.]

3.2

substrate

workpiece upon which deposition is to take place

[SOURCE: ISO 20523:2017, 3.1]

3.3

thin film

layer of material, typically less than 100 nm in thickness, deposited or grown on a substrate

Note 1 to entry: Films thinner than 10 nm are often called ultrathin films.

[SOURCE: ISO 18115-1:2023, 5.13]

4 Terms related to atomic layer deposition

4.1 General terms

4.1.1

precursor

reaction source used in atomic layer deposition process

Note 1 to entry: Metal films can be deposited by reducing precursors and removing ligands linked to metal atoms in atomic layer deposition process.

Note 2 to entry: Inorganic non-metals film can be deposited by oxidizing or reducing precursors and removing ligands linked to metal or non-metal atoms in atomic layer deposition process.

4.1.2

self-limiting reaction

reaction between precursor B and substrate with the chemically adsorbed precursor A, which automatically stops after the substrate is terminated by the remained ligands of precursor B

Note 1 to entry: During a typical atomic layer deposition process, precursor A is chemically adsorbed on the surface of a substrate, then precursor B will react with precursor A until adsorbed precursor A is completely consumed.

4.1.3

half chemical reaction

chemical reaction between one kind of precursor and substrate, which makes the substrate expose the remaining ligands of the precursor

4.1.4

growth rate

film thickness growth in each atomic layer deposition cycle

Note 1 to entry: Growth rate can be measured in situ by a spectroscopic ellipsometer.

4.1.5

atomic layer deposition window

temperature range in which atomic layer deposition reaction can occur

Note 1 to entry: In an atomic layer deposition window, the growth rate per cycle shows weak or no temperature dependence, which is closely related to precursors.

4.1.6

substrate temperature

temperature of substrate during atomic layer deposition

4.1.7

inert gas

gas that does not react with substrate, precursor and reactor

4.1.8

carrier gas

inert gas for carrying the precursor into the reactor

4.1.9

precursor exposure

process of the precursor entering the reaction zone and that adsorbs on the surface of a substrate

4.1.10

exposure time

time for precursor exposure to the surface of a substrate

4.1.11**inert gas purge**

process of inert gas entering the reaction zone to purge excess precursor and by products from substrate surface

Note 1 to entry: For high vacuum atomic layer deposition process, the precursor can be rapidly pumped away, which usually does not use inert gas purge.

4.1.12**vacuum degree**

degree of residual gas fraction in vapor deposition process

4.1.13**ultimate vacuum pressure**

lowest stable pressure of vacuum chamber under normal working condition

Note 1 to entry: The ultimate vacuum pressure is expressed in Pascals (Pa).

4.1.14**pumping time**

duration to draw the vacuum chamber from atmospheric pressure (10^5 Pa) to a specific pressure under normal vacuum system working condition

Note 1 to entry: The pumping time is expressed in seconds (s).

4.1.15**rate of pressure rise**

pressure increase per unit time in a vacuum chamber due to air leakage or internal deflation

Note 1 to entry: The rate of pressure rise is expressed in Pascals per second (Pa/s).

4.2 Film growth of atomic layer deposition**4.2.1****nucleation**

first step in the formation and transformation of nuclei that have the characteristics of new phase

4.2.2**nucleation site**

location where the precursor begins to react on the surface of a substrate

4.2.3**nucleation stage**

process in which incident atoms diffuse across the surface to grow to a certain size and form stable nuclei

4.2.4**island stage**

growth of a nucleus by adsorbing or directly receiving an incident atom in three dimensions

4.2.5**network stage**

process of island growth meeting and merging into a large surface area, adjusting the shape and reducing the free energy of the crystal inside, and connecting the large surface area to form a network structure

4.2.6**continuous stage**

network of grooves that gradually fills up to form a continuous film with the increase of atoms

4.2.7

selective atomic layer deposition

precursor that selectively reacts with certain sites of substrate surface in which atomic layer deposition films are prepared

4.2.8

selectivity

ratio of atomic layer deposition on the desired locations of the entire substrate

4.2.9

facet selectivity

precursors adsorbed on specific crystal faces

4.2.10

precursor bonding energy

energy required for precursors to react at the nucleation site

4.2.11

precursor adsorption energy

energy required for precursors adsorbing on the substrate surface

4.2.12

precursor activation energy

energy required for precursor that goes over the barrier for completing the half chemical reaction

4.3 Classification of atomic layer deposition

4.3.1

time separated atomic layer deposition

self-limiting reactions of precursors on a substrate in an atomic layer deposition cycle which are separated by time

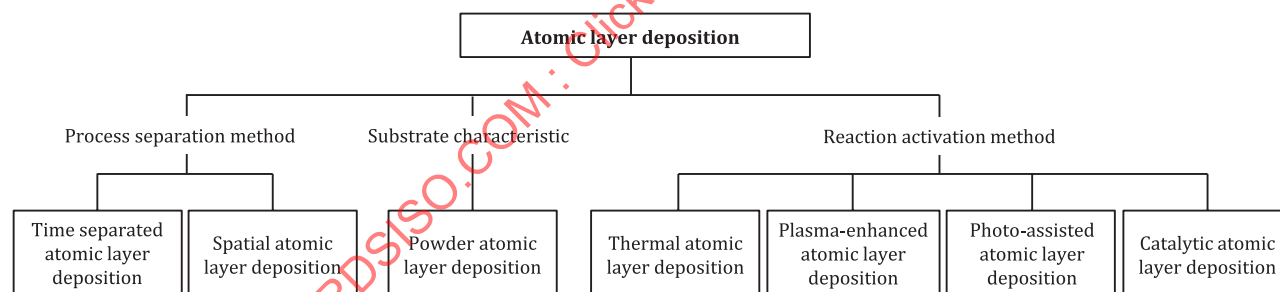


Figure 1 — Classification of atomic layer deposition

Note 1 to entry: [Figure 1](#) shows the classification of atomic layer deposition according to the process separation method, substrate characteristic and reaction activation method. According to the process separation method, atomic layer deposition can be classified as time separated atomic layer deposition and spatial atomic layer deposition. Besides planer substrate, atomic layer deposition involves powder atomic layer deposition by considering the substrate characteristic. According to the reaction activation method, atomic layer deposition can be classified as thermal atomic layer deposition, plasms-enhanced atomic layer deposition, photo-assisted atomic layer deposition and catalytic atomic layer deposition.

Note 2 to entry: [Figure A.1](#) gives the schematic diagram of a time separated atomic layer deposition.

4.3.2

spatial atomic layer deposition

atomic layer deposition that is achieved by alternately exposing a substrate to the locations containing different precursors or inert gas

Note 1 to entry: [Figure A.2](#) gives the schematic diagram of spatial atomic layer deposition.

4.3.2.1**rotary spatial atomic layer deposition**

relative motion of spatial atomic layer deposition is the rotational motion between substrate and nozzle

4.3.2.2**roll-to-roll spatial atomic layer deposition**

substrate of spatial atomic layer deposition that is flexible and that is wound by a roller wheel

4.3.2.3**gap**

distance between the nozzle outlet and the substrate surface

4.3.2.4**cross contamination**

chemical reaction that occurs when precursors directly contact with each other in gas phase

4.3.2.5**separate gas**

inert gas used to isolate different precursors to prevent cross contamination

4.3.2.6**substrate velocity**

velocity of substrate relative to the nozzle of precursor

4.3.3**powder atomic layer deposition**

process of atomic layer deposition by the reaction of precursors on powder surface

4.3.3.1**static powder atomic layer deposition**

powder that is static in a tray during atomic layer deposition

4.3.3.2**fluidized powder atomic layer deposition**

powder that is dispersed in a fluidized bed reactor during atomic layer deposition

4.3.3.3**rotary powder atomic layer deposition**

powder that is dispersed in a rotary reactor during atomic layer deposition

4.3.3.4**centrifugal fluidized powder atomic layer deposition**

powder that is dispersed in a fluidized bed coupled rotary reactor during atomic layer deposition

4.3.3.5**static electricity powder atomic layer deposition**

powder that is dispersed by electrostatic repulsion during atomic layer deposition

4.3.4**thermal atomic layer deposition**

chemical reactions between precursors and substrate that are activated at a certain temperature (typically between 50 °C to 350 °C)

4.3.5**plasma enhanced atomic layer deposition**

plasma generator that promotes precursors to form plasma and that enhances the chemisorption activity between precursors and substrate surface to facilitate atomic layer deposition

4.3.5.1

direct plasma atomic layer deposition

plasma enhanced atomic layer deposition with plasma generator close to substrate and plasma flow directly being applied on substrate surface to facilitate atomic layer deposition

4.3.5.2

remote plasma atomic layer deposition

plasma enhanced atomic layer deposition with plasma generator away from reaction chamber and deposition occurring at a location remote from plasma generator

4.3.6

photo-assisted atomic layer deposition

chemical reactions between precursors and substrate that are accelerated by introducing illumination (such as UV light)

4.3.7

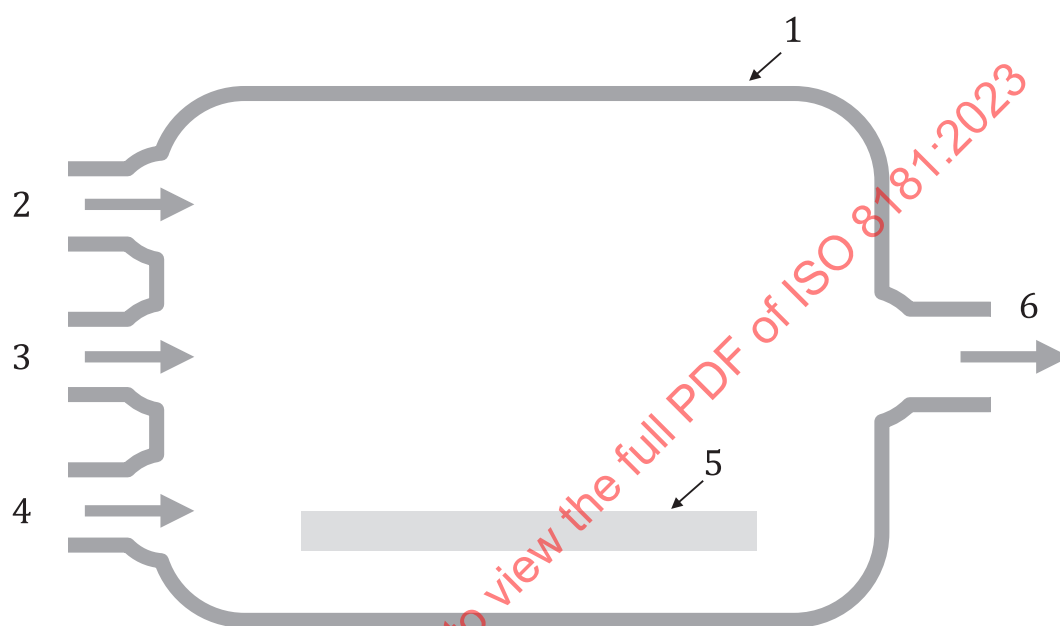
catalytic atomic layer deposition

chemical reactions between precursors and substrate that are accelerated by catalysts

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Annex A (informative)

Examples of schematic diagrams for a time separated ALD and a spatial ALD



Key

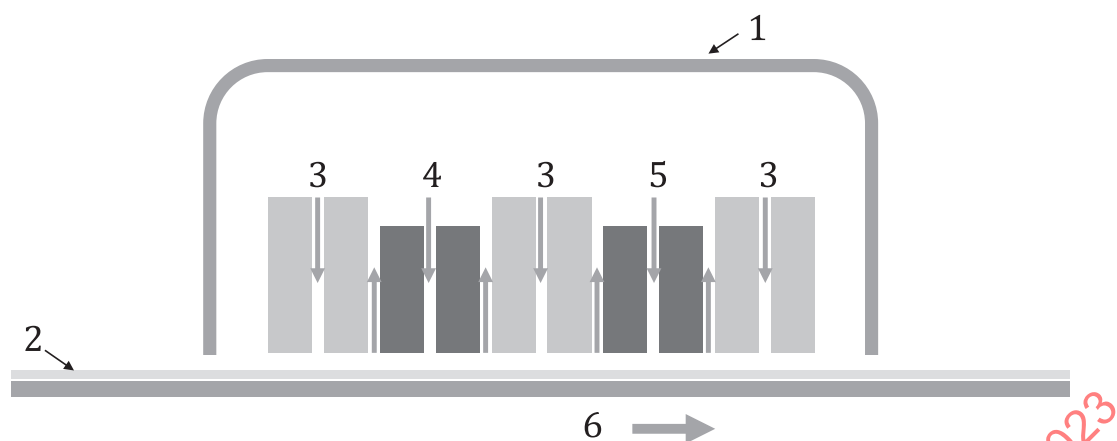
- 1 reaction chamber
- 2 precursor A
- 3 inert gas
- 4 precursor B
- 5 substrate
- 6 exhaust gas

Through the sequential introduction of different precursors and inert gases, the separation of reactants in time is achieved.

NOTE 1 The precursor and inert gas are introduced alternately.

NOTE 2 The substrate can be flat or powder.

Figure A.1 — Example of a schematic diagram for a time separated ALD



Key

- 1 reaction chamber
- 2 substrate
- 3 inert gas
- 4 precursor A
- 5 precursor B
- 6 substrate movement direction

The substrate moves through the precursor and the inert gas nozzle in sequence to achieve spatial isolation of the reactants.

NOTE The substrate moves in a certain direction and the nozzles are always in working condition.

Figure A.2 — Example of a schematic diagram for a spatial ALD