Chapter 1

Introductory Chapter: The Prominence of Thin Film Science in Technological Scale

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http://dx.doi.org/10.5772/67201

1. A succinct testimony of thin film science

Since antediluvian times, the term ‘thin film coating technology’ is more captivating towards mankind. More than 2000 eons ago, goldsmiths and silversmiths developed a variety of methods, including using mercury as an adhesive, to apply over thin films of metals to sculptures and other objects. The ancient mercury-based processes like fire gilding and silvering techniques were used for the surface coating of less precious substrates having thin layers made up of gold or silver. They developed the technology of thin-film coating that is unrivalled by today’s process for manufacturing DVDs, electronic devices, solar cells and other relevant products and used it on statues, amulets, jewels and more common objects.

In reference to the technological aspect, these workmen over 2000 years ago manage to produce valuable metal coatings as thin and adherent as possible, which not only saved luxurious metals but also enriched resistance to wear that would cause from sustained usage and circulation. In ancient days, the craftsmen were methodically organized these metals to construct functional as well as decorative artistic objects, without having any fundamental knowledge about the physico-chemical processes. The mercury-based techniques were also deceitfully used in ancient times to create objects such as coins and jewels that looked like they would be made of gold or silver but actually had a less precious core. Ingo et al. [1, 2] set forth to apply the modern analytical methods to reveal the ancients’ artistic secrets. By means of surface analytical methods, for example, selected area X-ray photoelectron spectroscopy and scanning electron microscopy combined with energy dispersive X-ray spectroscopy on Dark Ages objects such as St. Ambrogio's altar from 825 AD, they said that their discoveries endorse ‘the high level of proficiency achieved by the craftsmen and artists of these primordial periods who created objects of an imaginative qualities that would not be ameliorated in ancient times and have not yet been technologically advanced in modern ones’.

A widespread responsiveness has found on thin film studies in many advanced new areas of research in the combination of chemical, physical and mechanical sciences, which are based on prodigies with unique features of the thickness, structure, geometry of the film, etc. [3]. Whereas bearing in mind, a thin film matter contains two surfaces that are as close to each other that they could have a conclusive impact on the internal physical properties and methods of the substance, which would differ, therefore, in a reflective way from that of a bulk material. A new phenomenon is arisen due to the diminution in distance flanked by the surfaces and its mutual interaction. At this juncture, the one-dimensional structure of the material is abridged to an order of numerous atomic layers, which generate an intermediary scheme sandwiched between macro-molecular systems, thus it offers us a technique of studying the microphysical nature of different phenomena. Thin films are precisely suitable for applications in the field of microelectronics, opto-electronics, integrated optics, etc. Nonetheless, the physical properties of the films such as electrical resistivity do not considerably vary from the characteristics of the bulk material. The thickness is from a few tenths of nanometre to a few micrometres.

Albeit the erudition of thin film prodigies dates well back over an epoch, it is actually only over the last four decades, which they have been effectively used to a substantial extent in practical situations. The usages of thin and thick films are almost authoritative to the complete prerequisite of micro miniaturization. The growth of the computer technology would lead to an obligation for very high density systems of storage and it is this which has enthused utmost of the research on the opto-electronics, magnetic and optical properties of the thin films. Sundry thin film devices had been industrialized which might found themselves looking for the applications or perhaps more prominently market.

A wide range of thin film materials, its fabrication techniques, deposition processing, spectroscopic and the optical characterization would probe which are adopted to create many novel devices. Thin film deposition is usually divided into two broad categories [3, 4].

- **Physical deposition process**
- **Chemical deposition process**

Widespread thin film techniques are summarized in the flowchart of **Figure 1** [5, 53]. The films are often capable of producing films around 1 μm or less and the thick films are naturally in the range of 1–20 μm, the range of resistivities are 10 Ω/square to 10 MΩ/square, there are significant possibilities for building multi-layer structures. Though there are definite techniques that are only accomplished of producing thick films and these might include screen printing, electrophoretic deposition, flame spraying, glazing and painting.

Physical and chemical depositions are the two techniques that are used to create a very thin layer of material into a substrate. They are used greatly in the production of semiconductors where the very thin layers of p-type and n-type materials would create the necessary junctions. *Physical deposition* refers to a widespread range of technologies in that a material is released from the source and which would deposited on a substrate using mechanical, electromechanical or the thermodynamic processes. The two most general techniques of physical vapour deposition (PVD) are evaporation and sputtering. *Chemical deposition* is stated as when a volatile fluid precursor does a chemical change on a surface leaving a chemically deposited coating. When one tries to categorize deposition of films by chemical methods, one would find that they can be categorized into two classes. The first class is related to the chemical formation of the film from medium and typical methods included are chemical reduction plating, electroplating and vapour phase deposition. A second class is the formation of the respective film from

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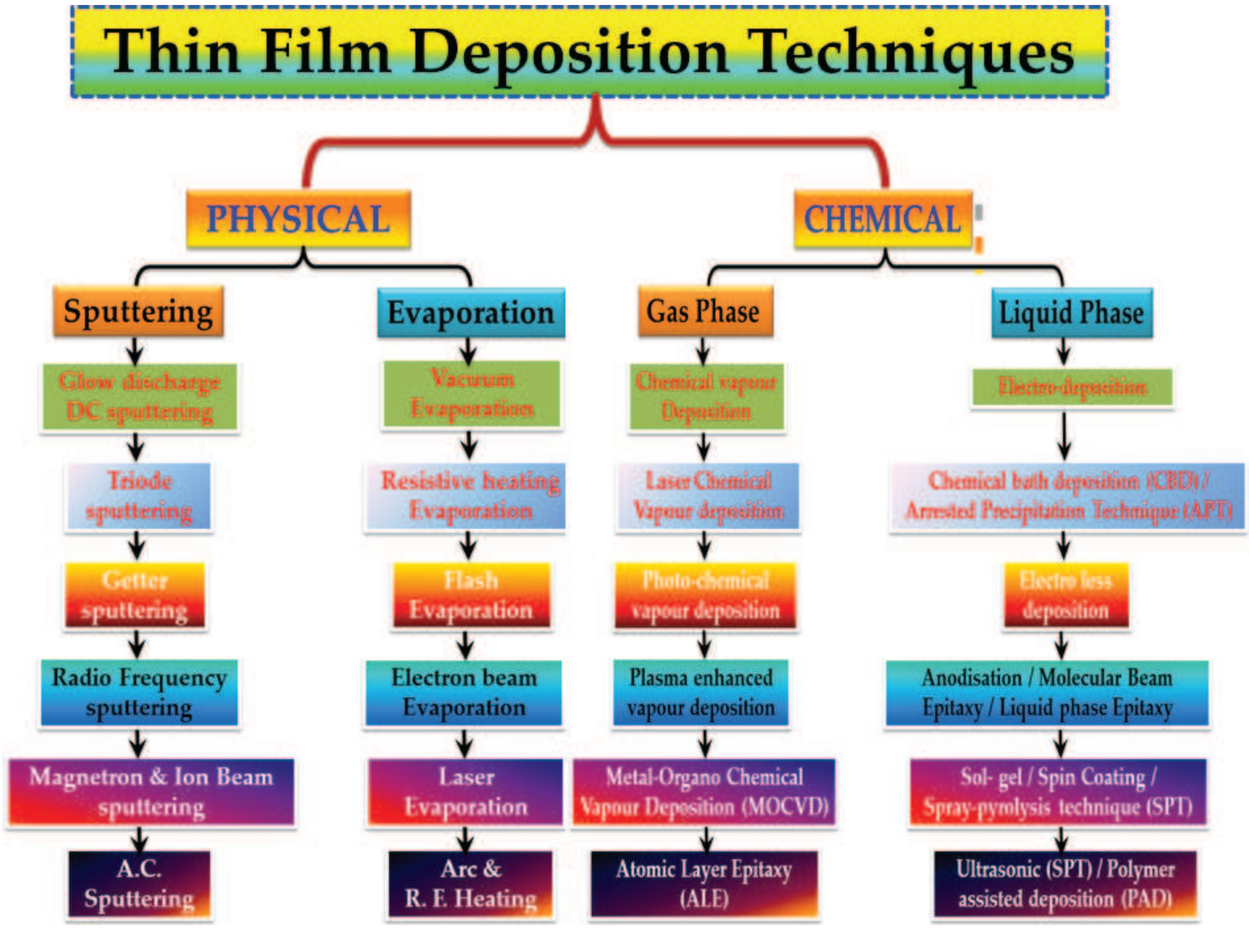

Figure 1. Flowchart illustrates the physical and chemical deposition process wide spread thin film techniques.

the precursor elements, e.g. iodization, gaseous iodization, sputtering ion beam implantation, thermal growth, CVD, MOCVD and vacuum evaporation that is used to produce the highest purity, reliable-performance solid materials in the semiconductor industry nowadays.

Relationship between the structure and property of thin films is the characteristics of such devices and forms the basis of thin film technologies. For example, in PVD (physical vapour deposition), a pure source material is gasified through evaporation, the application of the high power electricity, laser ablation and other few techniques. The gasified material would then condense on the substrate material to form the desired layer. However, by CVD (chemical vapour deposition), the chemical reactions might depend on thermal effects, as in vapour phase deposition and also the thermal growth. However, in all of these cases (**Figure 1**), a definite chemical reaction is a requirement to obtain as the form of final film [5, 53].

2. Technological advancements in the science of thin films

Thin film technology could be applied to various substrate materials, for example ceramics metals or polymers. The very common substrate materials are silicon, steel and glass. By appropriately cherry-picking the deposition materials and the technology, properties of the substrate material could be upgraded, enriched and tailor-made to meet the exceptional desires of a specific application. Furthermore, currently, thin film technologies are accessible that could be applicable to either flat substrates or objects with multifaceted geometrical silhouettes. Highlighting on device miniaturization and the technological parameters of alternate processes (such as thick film) are contributing to the expansion of the thin film industry and to the development of lower cost thin film equipment and processes. When the thin film is deposited, in many applications, it is obligatory to contour the film to a pre-established pattern. This is usually accomplished by lithography and etching. The construction device process is accomplished by ultimate and packaging steps (such as assembly), which differ based on the type of device. Everyone owns a numerous astounding moments to have a high regard for the remarkable engage in regeneration of novel thin film devices, the consequence and the good organization of the assistance offered through thin film devices to extend our prospect, in addition to reward for its fascinated defects to make ourselves with recent technological illusions.

The well-equipped novel thin film techniques have broad accessibility by means of ease procedure, sensitivity, selectivity, speed, accuracy and precision [6, 9, 34]. The novel applications of thin film devices have tendered innovative advancements in technology over few decades and these technological aspects were rapidly employed for cutting-edge research mostly in all the field of science and technology. **Table 1** presents the some major innovative advancement in technology associated with the applications of thin films in a broad spectrum.

Thin-film device fabrication technology has great advantages. Due to their characteristic features that they could be placed at virtually any wavelength in the broad region of transparency of their respective materials simply by varying the thicknesses of their layers, and, once a design had been established, the time for the production is exceptionally of short duration. In addition, a large field of application of thin film systems is that they act as laser mirrors, anti-reflex coatings and other optically active surface modifications. In the optical industry, they have been coated on substrates which would ensure the stable mechanical and other specific properties. Thin films could similarly be present in opto-electronic, magnetic and electronic apparatuses which could only be factory-made due to the specific physical properties of thin films which might vary considerably in reference to the bulk material. A significant example for this case is hard disk read heads due to the giant magnetoresistance effect (GMR). These are having the special properties with a combination of insulating and magnetic thin flms.

The technological achievements in modern thin film synthesis over the past decade subsequently lead to the utilization of outstanding properties and development of a wide range of applications in various engineering fields. As a result, the current activity in the thin-film device fabrication technology has been correlated and to expand our prospects based on the new ideas in the field of nanotechnology, LEDs and displays, photovoltaics/solar cells, environmental, biological science and so on. The current experimental standards for the assessment of environmental risk are the ones, which rely on the growth inhibition triggered by the chemical substance and would not include qualitative evaluation such as the process of enunciating

http://dx.doi.org/10.5772/67201

Field	Application with examples
Engineering/ Processing	***Tribology***: • Protective coatings to reduce wear [6, 7] • Corrosion and erosion [8] • Low friction coatings [9] ***Self-supporting coatings:*** • Refractory metals for rocket nozzles [10] • Crucibles [11] • Pipes [12] ***Others:*** • Hard coatings for cutting tools [13] • Surface passivation [14] • Protection against high temperature corrosion [15] • Decorative coatings [16] • Catalyzing coatings [17]
Optics	• Antireflex coatings ("multicoated optics") [18] • Highly reflecting coatings (laser mirrors) [19] • Interference filters [20] • Beam splitter and thin film polarizers [21] • Integrated optics [22]
Optoelectronics	• Photodetectors [23] • Image transmission [24] • Optical memories [25] • LCD/TFT [26]
Electronics	• Passive thin film elements [27] (resistors, condensers, interconnects) • Active thin film elements [28] (transistors, diodes) • Integrated circuits [29] (VLSI, very large-scale integrated circuit) • CCD (charge coupled device) [30]
Electricity (without semiconductors)	• Insulating/conducting films [31] e.g. for resistors, capacitors • Piezoelectric devices [32]
Cryotechnics	• Superconducting thin films, switches, memories [33] • SQUIDS (superconducting quantum interference devices) [34]
Mechanics	• "Hard" layers (e.g. on drill bits) [35] • Adhesion providers [36] • Friction reduction [37]

Field	Application with examples
Magnetics	• Hard” discs [38] • Video/audio tape [38]
Sensorics	• Data acquisition in aggressive environments and media [39] • Telemetry [40] • Biological sensorics [41]
Chemistry	• Diffusion barriers [42] • Protection against corrosion/oxidation [43] • Sensors for liquid/gaseous chemical [44]
Biomedicine	• Biocompatible implant coating [45] • Neurological sensors [46]
New materials	• Metastable phases: metallic glasses [47, 48] • Spheroidization of high melting point materials (diameter 1–500 μm) [49] • High purity semiconductors (GaAs) [50]
(Alternative) energies	• Solar collectors and solar cells [51] • Thermal management of architectural performance of ETFE foils (metal-coated foils) [52]

Table 1. Innovative advancement with technological applications in thin films [53].

toxicity. Thus, it is figured out that this only evaluation is inadequate for building improvement, which leads to ecological preservation and to deep circumvention against human health.

3. Conclusion

Persistent to the above discussion, thin film is not only well thought-out a forerunner across the globe with highly novel scientific developments; however, facts also establish that it has been and would prolong to be imperious towards path-breaking research against novel applications for the societal benefits. Amongst the major noteworthy developments in different fields of nanotechnology, LEDs and displays, photovoltaics/solar cells, environmental, and medical diagnostics are the most important worldwide challenges so far. Progress must continue in the novel thin film techniques, which is used in the field of spectral imaging, time-correlated single-photon counting, kinetic chemical reaction rates, non-invasive optical biopsy and visual implants. Thus, research on unique thin film technological achievements might pave way for coating thin films in an atomic scale that may perhaps turn out to be the future signs of green energy in the upcoming scenario.

Acknowledgements

Work incorporated in this chapter was partially supported by the Department of Science and Technology (SR/FTP/PS-135/2011) Govt. of India. The authors apologize for inadvertent omission of any pertinent references.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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