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DEVOLOPMENT OF THIN FILM COATING TECHNOLOGY

INTRODUCTION

Surface properties of materials can affect the efficiency and behavior of the material when in service. Modifying and tuning these surface properties to meet the specific demand for better performance is feasible and has been vastly employed in a different aspect of life. This can be achieved by coating the surface via deposition of thin films. The deposition techniques determine virtually all the properties of the thin film and can also be used to modify the existing properties [1]. Several modern cutting edge technologies, including the superconducting technology, green energy generation/storage technology, and the emerging 5G networks technology, have some form of thin-film coatings [2].

Since antediluvian times, the term ‘thin film coating technology’ is more captivating towards mankind. More than 2000 years 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. 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 [3]. 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. The use of thin films to enhance the physical and chemical properties of materials is ubiquitous in today’s world. The adjective “thin” in the term “thin film” is ambiguous and poorly defined. It is used to describe, depending on the application, “coating” layers ranging in thickness from less than a single atomic layer (a partial monolayer) to films that are a significant fraction of a millimeter thick. Examples are shown in Fig. 1: copper metallization layers for electronic communication among billions of transistors in a silicon integrated-circuit; coated architectural glass in office buildings for which the thin films are designed to enhance energy efficiency and comfort by, and coated cutting tools developed to reduce friction and wear during use and, hence, increase tool lifetimes. Other common examples include magnetic thin films for electronic data storage; transparent conductive oxide and absorber layers in solar cells; thin film resistors and dielectrics; superconducting thin films for high-frequency devices; corrosion-, friction-and wear-protective layers on automotive and airplane engine parts (spark-plug electrodes, pistons, cylinders, turbine blades, etc.); and multiple layers on eyeglasses to correct vision, minimize ultraviolet light transmission, and provide scratch resistance [4].

Figure 1. Coated tools: (Left panel) Copper interconnect metallization in a transistor, (Middle panel) Coated architectural glass in office buildings, (Right panel) TiN, TiAlN, and TiB_2 [4]

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. 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 [4].

HISTORICAL OVERVIEW

Coatings history extends further into the past than does any other facet of polymer science [5]. Although today's coatings serve both a protective and decorative function in most instances, prehistoric coatings were purely decorative. The earliest documented purposefully made inorganic thin films were gold layers produced chemo-mechanically, for decorative (and later, optical) applications, by the Egyptians during the middle bronze age, more than 5000 years ago. Gold films, with thicknesses <3000A ° have been found in ancient tombs [5]. spectacular specimens of early thin-film technology were found in the tomb of Pharaoh Tutankhamun (“King Tut” 18th Dynasty, ruled ~1332 - 1323 BC) [4]. In fact, the production of gold leaf, primarily for decorative purposes, remained a viable industry for craftsmen until the development, in the mid-1930s, of roll-to-roll sputter and evaporative coating technologies [4].

In the middle Ages; the use of paint as a preservative for exposed wood surfaces was extensive, considering the fact that the coatings were handmade and used costly raw materials. It was not until the Industrial Revolution when machinery required protection against corrosion that large-scale production of coatings began. Events since the Industrial Revolution have been responsible for the emergence of coatings as a high - technology industry. The main benchmarks in the history of thin film technology development can be summarized as follows:

~ 1650: Observation and interpretation of interference patterns (e. g. oil on water) by R. Boyle, R. Hooke, I. Newton.

~1850: Development of first deposition techniques (M. Faraday; W. Grove; T. A. Edison) and of methods of thickness determination (Arago; Fizeau; Wernicke; Wiener), Commercial introduction of electrochemistry (Galvanics) for gold plating of uniform-accessories.

~1940: Industrial manufacturing of coatings for optical, electronic and mechanical applications (mostly military).

~1965: Thin film technology develops to an integral part of the mass manufacturing processes in semiconductor and optical industry.

~1990: Thin films of High Tc-Superconductors.

~1995: Thin film processing allows for the tailoring of microstructures of atomic and mesoscopic dimensions (“Quantum-Dots “by PVD, “Cu-technology” by electrochemistry applied to integrated circuits).

~2000: Manufacturing of Nano-crystalline materials with defined composition and structure for applications as protective coatings and in tribology, Deposition of highly ordered two and three dimensional objects with sizes in the nm range.

~2004: Up scaling of complex reactive coating processes for industrial applications (coatings on glass, thermal management), Combinatory investigation of ternary and quaternary material systems.

~2006: Investigation of organic coatings leads to the emergence of organic electronics (OLED, printable circuits).

~2010: Preparation and characterization of the prototype two dimensional (2D) materials, Graphene, Introduction of reliable solid state touch screens to communication media (Smart phones).

~2015: Generation of hetero structures made from 2D materials, Approaches to manufacture flexible electronic devices consisting of ultrathin materials.

APPLICATIONS

Today; the application of thin films has a broad spectrum than ever, this application has a wide interface with many fields and disciplines, from engineering and surface modification to prevent corrosion to biomedicine and alternative energy, the main application areas is summarized below with specific examples of usage [4].

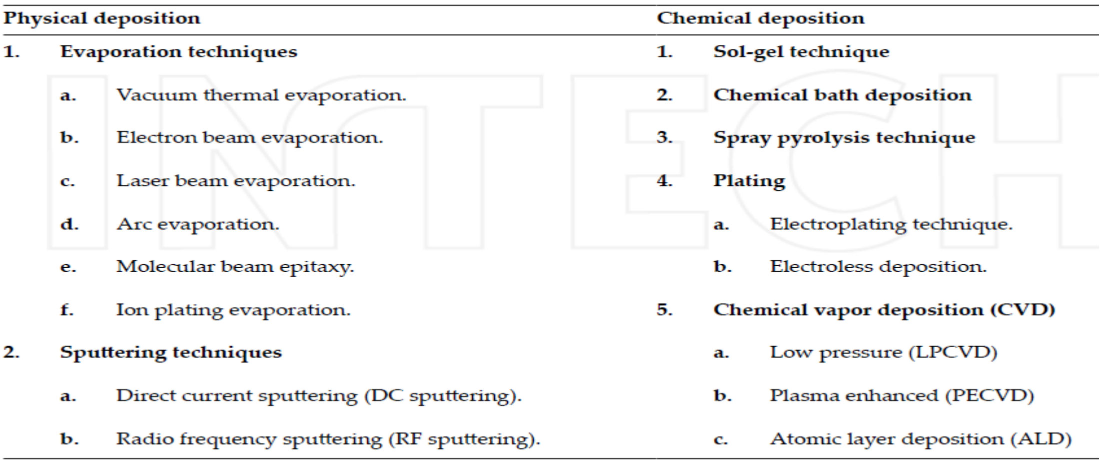
Application area	Examples
Engineering/Processing	Tribological Applications: Protective coatings to reduce wear, corrosion and erosion, low friction coatings
	Hard coatings for cutting tools
	Surface passivation
	Protection against high temperature corrosion
	Self-supporting coatings of refractory metals for rocket nozzles, crucibles, pipes
	Decorative coatings
	Antireflex coatings ("Multicoated Optics")
Optics	Highly reflecting coatings (laser mirrors)
	Beam splitter and thin film polarizer
	Integrated optics
Electronics	Passive thin film elements (Resistors, Condensers, Interconnects)
	Active thin film elements (Transistors, Diodes)
	Integrated Circuits (VLSI, Very Large Scale Integrated Circuit)
	CCD (Charge Coupled Device)
	Superconducting thin films, switches, memories
Cryotechnics	SQUIDS (Superconducting Quantum Interference Devices)
	Super hard carbon ("Diamond")
New Materials	Amorphous silicon
	Detestable phases: Metallic glasses
	Ultrafine powders (diameter < 10nm)
	Spheroidization of high melting point materials (diameter 1-500 μm)
	High purity semiconductors (GaAs)
	Solar collectors and solar cells
(Alternative) Energies	Thermal management of architectural glasses and foils
	Thermal insulation (metal coated foils)
Magnetic Applications	Audio, video and computer memories
	Magnetic read/write heads
Biomedicine	Biocompatible implant coatings
	Neurological sensors

METHODS AND TECHNOLOGIES

The deposition process of a film can be divided into three basic phases: Preparation of the film forming particles (atoms, molecules), Transport of the particles from the source to the substrate and Adsorption of the particles on the substrate and film growth. The prominent subsets of deposition techniques are physical vapor deposition (PVD) and chemical vapor deposition (CVD). The distinguishing feature between PVD and CVD is in the vapor. In PVD, the vapor is made up of atoms and molecules that simply condense on the substrate, and for CVD, the vapor undergoes a chemical reaction on the substrate which resulted into a thin film. The Methods used under these two types are summarized in table 1.

Table 1

Thin films deposition Methods [6]



Physical deposition			**Chemical deposition**		
1.	**Evaporation techniques**		**1.**	**Sol-gel technique**	
	a.	Vacuum thermal evaporation.	**2.**	**Chemical bath deposition**	
	b.	Electron beam evaporation.	**3.**	**Spray pyrolysis technique**	
	c.	Laser beam evaporation.	**4.**	**Plating**	
	d.	Arc evaporation.		**a.**	Electroplating technique.
	e.	Molecular beam epitaxy.		**b.**	Electroless deposition.
	f.	Ion plating evaporation.	**5.**	**Chemical vapor deposition (CVD)**	
2.	**Sputtering techniques**			**a.**	Low pressure (LPCVD)
	a.	Direct current sputtering (DC sputtering).		**b.**	Plasma enhanced (PECVD)
	b.	Radio frequency sputtering (RF sputtering).		**c.**	Atomic layer deposition (ALD)

Physical Vapor Deposition

Physical vapor deposition (PVD) is a broad term used to describe the deposition of atoms, molecules, or the combination of atoms and molecules via condensation. In general, the term PVD encompasses two major categories: evaporation techniques, and sputtering techniques [7]. Each of these two main techniques has a combination of sub - coatings methods.

Evaporation Techniques

Evaporation methods are considered from the common coating deposition methods of materials in the form of thin-layer films. The general mechanism of these methods is obtained by changing the phase of the material from solid phase to vapor phase and converting again to solid phase on the specific substrate. It takes place under vacuum or controlled atmospheric condition [7].

A variety of different techniques are available for depositing evaporative coatings such as reactive evaporation, plasma assisted or activated reactive evaporation, and molecular beam epitaxy.

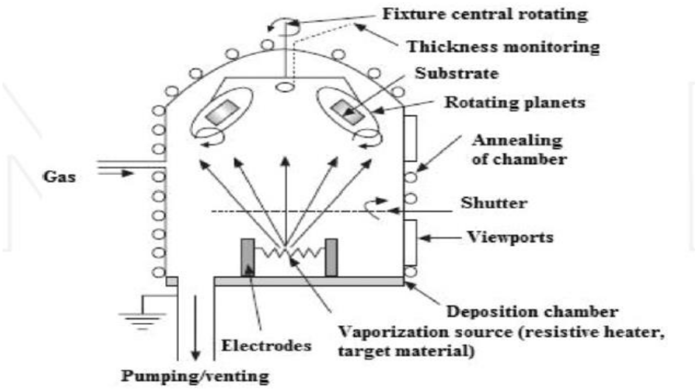


Figure 2. Schematic diagram for thermal evaporation technique

Sputtering

Sputtering is a technique used to create thin films; and it's mostly used for depositing metal and oxide films by controlling the crystalline structure and surface roughness. It is extensively used in the hard coating industry. High quality coatings of refractory compounds and metals can be readily produced with good adhesion and composition control. In addition, since sputtering is not a thermally activated process, it is not associated with high temperature requirements like other coating processes [8]. During the sputtering process, a source (or target) is placed in a high vacuum and bombarded with gas ions (typically argon) which have been accelerated by high voltage, producing a glow discharge or plasma. Atoms from the target are physically ejected by the momentum transfer and travel across the vacuum chamber and are deposited on a substrate surface. Since the process is performed under low pressure, the mean-free path of the target atoms is relatively long, thus permitting the ejected atoms to condense on the intended surface.

The general disadvantages of sputtering include a relatively low deposition rate and a line-of-sight deposition characteristic which make the coating of deep holes and trenches difficult. However, an advantage of sputtering is that the high energy of sputtered particles improves adhesion and produces a denser and more homogenous coating than evaporation, Basic components of a magnetron sputtering system is shown in fig. 2.

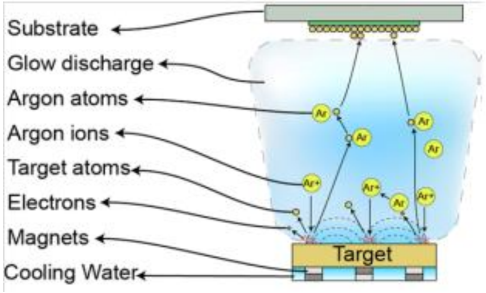


Figure 3. The basic components of a magnetron sputtering system [9]

Chemical Vapor Deposition

One of the most widely used coating deposition methods is the Chemical Vapor Deposition (CVD). CVD, like PVD, is a vapor deposition process where the deposition species are atoms, molecules, or a combination of the two. An important recent trend is the tendency for the two processes, CVD and PVD, is to merge. For instance, CVD processes now make extensive use of plasma (a physical phenomenon) and, conversely, reactive evaporation and reactive sputtering take advantage of chemical reactions in the deposition environment. Consequently, the differences between the two processes can often become blurred. Nevertheless, the CVD process may be defined as the deposition of a solid on a heated surface from a chemical reaction in the vapor phase. The CVD process has important advantages such as the high deposition therefore thick coatings (in some cases centimeters) can be readily obtained and it is generally competitive, in some cases, more economical than PVD processes. However, the process is most versatile at relatively high temperatures (600°C) and many substrates are not thermally stable at these temperatures, In addition; Starting materials (i.e., chemical precursors) with high vapor pressures are required, these are often hazardous and at times extremely toxic. By-products of CVD reactions are also toxic and corrosive and must be neutralized, which may be a costly operation.

CONCLUSIONS

Thin film coatings has been known to be used since ages, the science of thin film and the deposition techniques and technologies evolved and developed through the time to results in a wide use and wide applications. 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, photovoltaic/solar cells, environmental, and medical diagnostics are the most important worldwide challenges so far. The deposition techniques determine virtually all the properties of the thin film and can also be used to modify the existing properties. Proper consideration needs to be given to the deposition techniques depending on the area of application because not all the deposition techniques result into the identical properties such as microstructure, surface morphology, optical, corrosion and hardness.

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RADIATION EFFECTS OF SIC ON NUCLEAR REACTORS

ABSTRACT

Silicon carbides have enjoyed both fundamental study and practical application since the early days of nuclear materials science. In the past decade, with the increased interest in increasing efficiency, solving the real issues of waste disposal, and the constant mission to improve safety of nuclear reactors, silicon carbide has become even more attractive. This ceramic material has wide range of applications due to its high strength, low density, thermal shock resistance. The purpose of this paper is to discuss recent research that does not only strives to understand the remarkable radiation stability of SiC but the radiation effect of SiC under high temperature. This article will expound on the fabrication of SiC, the mechanical behavior and thermal stabil-