Chapter 3. Applications of Thin Film, Thin Films Deposition Processes and Characterization Techniques

Part A: Applications of Thin Films

Part B: Thin Film Deposition Processes

Part C: Characterization Techniques

A: Applications of Thin Films

The field of material science and engineering community's ability to conceive the novel materials with extraordinary combination of chemical, physical and mechanical, properties has changed the modern society. There is an increasing technological progress. Modern technology requires thin films for different applications. Thin film technology is the basic of astounding development in solid state electronics. The usefulness of the optical properties of metal films, and scientific curiosity about the behavior of two-dimensional solids has been responsible for the immense interest in the study science and technology of the thin films. Thin film studies have directly or indirectly advanced many new areas of research in solid state physics and chemistry which are based on phenomena uniquely characteristic of the thickness, geometry, and structure of the film.

When we consider a very thin film of some substance, we have a situation in which the two surfaces are so close to each other that they can have a decisive influence on the internal physical properties and processes of the substance, which differ, therefore, in a profound way from those of a bulk material. The decrease in distance between the surfaces and their mutual interaction can result in the rise of completely new phenomena. Here the one dimension of the material is reduced to an order of several atomic layers which creates an intermediate system between macro systems and molecular systems, thus it provides us a method of investigation of the microphysical nature of various processes. Thin films are especially appropriate for applications in microelectronics and integrated optics. However the physical properties of the films like electrical resistivity do not substantially differ from the properties of the bulk material. For a thin film the limit of thickness is considered between tenths of nanometer and several micrometers.

Thin film materials are the key elements of continued technological advances made in the fields of optoelectronic, photonic, and magnetic devices. The processing of materials into thin films allows easy integration into various types of devices. The properties of material significantly differ when analyzed in the form of thin films. Most of the functional materials are rather applied in thin film form due to their specific electrical, magnetic, optical properties or wear resistance. Thin film technologies make use of the fact that the properties can particularly be controlled by the thickness parameter. Thin films are formed mostly by deposition, either physical or chemical methods. Thin films, both crystalline and amorphous, have immense importance in the age of high technology. Few of them are: microelectronic devices, magnetic thin films in recording devices, magnetic sensors, gas sensor, A. R. coating, photoconductors, IR detectors, interference filters, solar cells, polarizer's, temperature controller in satellite, superconducting films, anticorrosive and decorative coatings.

Although the study of thin film phenomena dates back well over a century, it is really only over the last four decades that they have been used to a significant extent in practical situations. The requirement of micro miniaturization made the use of thin and thick films virtually imperative. The development of computer technology led to a requirement for very high density storage techniques and it is this which has stimulated most of the research on the magnetic properties of thin films. Many thin film devices have been developed which have found themselves looking for an application or, perhaps more importantly market. In general these devices have resulted from research into the physical properties of thin films.

Secondly, as well as generating ideas for new devices, fundamental research has led to a dramatic improvement in understanding of thin films and surfaces. This in turn has resulted in a greater ability to fabricate devices with predictable, controllable and reproducible properties. The cleanliness and nature of the substrate, the deposition conditions, post deposition heat treatment and passivation are vital process variables in thin film fabrication. Therefore, prior to this improvement in our understanding of thin films, it has not really been possible to apply them to real devices.

Thirdly, much of the finance for early thin film research originated from space and defense programs to which the device cost is less important than its lightweight and other advantages, the major applications of thin film technology are not now exclusively in these areas but rather often lie in the domestic sector in which low cost is essential .

Thin film materials have already been used in semiconductor devices, wireless communications, telecommunications, integrated circuits, rectifiers, transistors, solar cells, light-emitting diodes, photoconductors, light crystal displays, magneto-optic memories, audio and video systems, compact discs, electro-optic coatings, memories, multilayer capacitors, flat-panel displays, smart windows, computer chips, magneto-optic discs, lithography, micro electromechanical systems (MEMS), and multifunctional emerging coatings, as well as other emerging cutting technologies.

a. Optical Coatings:

An optical coating is one or more thin layers of material deposited on an optical component such as a lens or mirror, which alters the way in which the optic reflects and transmits light. One type of optical coating is an antireflection coating, which reduces unwanted reflections from surfaces, and is commonly used on spectacle and photographic lenses. Another type is the high-reflector coating which can be used to produce mirrors which reflect greater than 99.99% of the light which falls on them. More complex optical coatings exhibit high reflection over some range of wavelengths, and anti-reflection over another range, allowing the production of dichroic thin-film optical filters.

b. Photovoltaic Cells:

In the familiar rigid solar panel, the energy of incoming photons is converted to electricity in cells containing two thin layers of crystalline silicon. What makes roll-to-roll production of flexible film solar products possible is replacement of the crystalline silicon with amorphous silicon, supplied in high-solids slurries that can be deposited onto substrates by web-converting processes like slot die coating. Microlayer film, EDI can outfit its Contour cast film dies with a new system, based on technology licensed from ‘The Dow Chemical Company’, which makes it possible to produce film of standard thickness, yet with dozens of exceedingly thin ‘micro-layers’. The multiple layer-to-layer interfaces create a torturous path for gas molecules and thus substantially increase the barrier properties of the film. This is critical for photovoltaic applications, which require barrier layers to prevent performance losses caused by infiltration of oxygen or moisture vapour.

Many in the solar power industry and the investment community believe the arrival of grid parity, the point when cost of electricity generated by a rooftop photovoltaic (PV) cell system is equivalent to that purchased from an electrical utility will mark a major inflection point for the market that will deliver a huge increase in growth. However, even when true grid parity arrives, it’s unlikely to generate an abrupt rise in solar system installations due to the high upfront costs and the long-term return of investing in a rooftop photovoltaic system. In fact, growth is set to moderate during the years when grid parity arrives for various regions of the world as the industry enters a more mature phase.

c. Semiconductor:

Historically, the semiconductor industry has relied on flat, two-dimensional chips upon which to grow and etch the thin films of material that become electronic circuits for computers and other electronic devices. This thin layer (only a couple of hundred nanometers thick) can be transferred to glass, plastic or other flexible materials, opening a wide range of possibilities for flexible electronics.

In addition, the semiconductor film can be flipped as it is transferred to its new substrate, making its other side available for more components. This doubles the possible number of devices that can be placed on the film. By repeating the process, layers of double-sided, thin-film semiconductors can be stacked together, creating powerful, low-power, three-dimensional electronic devices. "It's important to note that these are single-crystal films of strained silicon or silicon germanium. The strain is introduced in the way we form the membrane. Introducing strain changes the arrangement of atoms in the crystal such that we can achieve much faster device speed while consuming less power."

For non-computer applications, flexible electronics are beginning to have significant impact. Solar cells, smart cards, radio frequency identification (RFID) tags, medical applications, and active-matrix flat panel displays could all benefit from the development. The techniques could allow flexible semiconductors to be embedded in fabric to create wearable electronics or computer monitors that roll up like a window shade. "This is potentially a paradigm shift. The ability to create fast, low-power, multilayer electronics has many exciting applications. Silicon germanium membranes are particularly interesting. Germanium has a much higher adsorption for light than silicon. By including the germanium without destroying the quality of the material, we can achieve devices with two to three orders of magnitude more sensitivity." That increased sensitivity could be applied to create superior low-light cameras, or smaller cameras with greater resolution.

d. Photo Electrochemical Cells (PEC):

In photo electrochemical experiments, irradiation of an electrode with light that is absorbed by the electrode material causes the production of a current (a photocurrent).

The dependence of the photocurrent on wavelength, electrode potential, and solution composition provides information about the nature of the photo process, its energetics, and its kinetics. Photocurrents at electrodes can also arise because of photolytic processes occurring in the solution near the electrode surface. Photo electrochemical studies are frequently carried out to obtain a better understanding of the nature of the electrode-solution interface. Photo electrochemistry and Electro generated Chemiluminescence photocurrent can represent the conversion of light energy to electrical and chemical energy; such processes are also investigated for their potential practical applications. Since most of the studied photo electrochemical reactions occur at semiconductor electrodes, we will review briefly the nature of semiconductors and their interfaces with solutions. Consideration of semiconductor electrodes also helps in gaining a microscopic understanding of electron-transfer processes at solid-solution interfaces.

e. Optoelectronic Lenses:

An optoelectronic thin-film chip, comprising at least one radiation-emitting region in an active zone of a thin-film layer and a lens disposed downstream of the radiation-emitting region, said lens being formed by at least one partial region of the thin-film layer, the lateral extent of the lens being greater than the lateral extent of the radiation-emitting region. The thin-film layer is provided for example by a layer sequence which is deposited epitaxial on a growth substrate and from which the growth substrate is at least partly removed. That is to say that the thickness of the substrate is reduced. In other words, the substrate is thinned. It is furthermore possible for the entire growth substrate to be removed from the thin-film layer. The thin-film layer has at least one active zone suitable for generating electromagnetic radiation. The active zone may be provided for example by a layer or layer sequence which has a pn junction, a double heterostructure, a single quantum well structure or a multiple quantum well structure. Particularly preferably, the active zone has at least one radiation-emitting region. In this case, the radiation-emitting region is formed for example by a partial region of the active zone. Electromagnetic radiation is generated in said partial region of the active zone during operation of the optoelectronic thin-film chip.

f. Flat Panel Displays:

Developed from the Mykrolis contamination control technologies, Energies provides a broad portfolio of liquid and gas contamination control technologies for the flat panel display fabrication. The Flat Panel Display (FPD) fabrication environment is among the world's most competitive and technologically complex. Device designers and manufacturers continually strive to satisfy the worldwide consumer's appetite for larger displays, greater pixel resolution and feature-rich performance – all at a lower cost than the previous generation of technology. The need to control contamination in air, gas and liquid process streams is now a paramount focus of process engineers and designers. Entergy provides the solutions to succeed under these extreme conditions.

g. Data Storage:

As the data storage density in cutting edge microelectronic devices continues to increase, the superparamagnetic effect poses a problem for magnetic data storage media. One strategy for overcoming this obstacle is the use of thermomechanical data storage technology. In this approach, data is written by a nanoscale mechanical probe as an indentation on a surface, read by a transducer built into the probe, and then erased by the application of heat. An example of such a device is the IBM millipede, which uses a polymer thin film as the data storage medium. It is also possible, however, to use other kinds of media for thermomechanical data storage, and in the following work, we explore the possibility of using thin film Ni-Ti shape memory alloy (SMA). Previous work has shown that nanometer-scale indentations made in martensite phase Ni-Ti SMA thin films recover substantially upon heating. Issues such as repeated thermomechanical cycling of indentations, indent proximity, and film thickness impact the practicability of this technique. While there are still problems to be solved, the experimental evidence and theoretical predictions show SMA thin films are an appropriate medium for thermomechanical data storage.

h. Super Capacitor:

Since first patents were in the 1950, the idea of storing charge in the electric double layer that founds at the interface between a solid and an electrolyte has presented itself as an attractive notation while was considerable development was carried out by the slander oil company, Cleveland, Ohio (SOHIO) in the 1960 a lack of sales lead them to license the technology to Nippon electric company. The first high power double layer capacitor were developed for military applications by the pinnacle research institute in 1982.

Conventional capacitor stores energy electrostatically on two electrode separated by a dielectric, the capacitance of which is C= €A/d, where € being the dielectric constant, A surface area and d the dielectric thickness. In a double layer capacitor, charges accumulate at the boundary between electrode and electrolyte to form two charge layers with separation of several Angstroms. Super capacitors are electrochemical energy storage device.

i. Gas Sensors:

Advancements in micro technology and the evolution of new nonmaterial and devices have been playing a key role in the development of very accurate and reliable sensors. The technology of sensors has developed tremendously in the last few years owning many scientific achievements from various experiments, offering newer challenges and opportunity to the quest for every smaller devices capable of molecular level imaging and monitoring of pathological samples and the macromolecules has lately gained the focus of attention of the scientific community, particularly for remote monitoring due to the increasing need for environmental safety and health monitoring.

Gas sensors generally operate different principles and various gas sensing elements have been developed have been past years, out of which resistive metal oxide sensors comprise a significant part. However these sensing elements typically operate at an elevated temperature for maximum performance. This makes higher power consumption which is not suitable for the inflation. Over the last decayed carbon nanotube has attracted considerable attention, and great efforts have been made to exploit their unusual electronic and mechanical properties. These properties make them potential candidates for building blocks of active materials in Nano electronics, field emission devices, gas storage and gas sensors. Among these the room temperature gas sensing property is very attractive for many applications.