Recent Advances in Energy Storage and Photoelectric Conversion Films

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Photoelectric conversion is one of the important ways for humans to obtain and utilize energy. Understanding the optical physics of materials and thin-film devices is the basis for photoelectric conversion and is also one of the most important research contents of condensed matter physics. At present, the main form of photoelectricity conversion is solar cells, and the main form of electricity conversion is a light-emitting diode (LED). Lithium batteries, sodium batteries, zinc batteries, supercapacitors and so on are typical representatives of energy storage materials. In recent years, great progress has been made in optimizing the preparation process and designing the device structure of photoelectric conversion and energy storage materials, which has shown a very attractive application prospect in the field of batteries and LED.

In recent years, researchers have carried out a series of studies on the relationship between photoelectric conversion and the composition, structure, physical properties and device performance of energy storage materials, including composition design, controllable preparation, structural properties and photophysical properties of corresponding thin-film devices.

Manufacturing, design and testing of photoelectric conversion and energy storage materials, including various batteries, supercapacitors, various films and LEDs.

Advanced energy storage technology [1] plays an increasingly important role in the development of national technology. The development of energy storage technology is closely related to the progress of energy storage materials [2]. With the development of a series of power generation technologies such as solar, wind, tidal, geothermal and fuel cells, advanced energy storage technologies are needed to store energy efficiently to meet the needs of storing and modulating power output. At present, research on energy storage materials is very active, including solar cells, lithium batteries, sodium batteries, zinc batteries and supercapacitors and other energy storage materials. New energy storage technology and material system keep emerging, and the index of energy storage technology keeps breaking through. At the same time, great progress has been made in interface reaction, composition and design, controllable preparation, etc.

A semiconductor light-emitting diode (LED) [3] is a device that converts electrical energy into light energy by combining the radiation of electrons and holes in semiconductor materials. LED is recognized as the green light source of the 21st century since, compared with the traditional light source, it has the advantages of energy saving, environmental protection and high efficiency. Nowadays, thin-film materials [4] have been applied more and more in electronics, information, aviation technology and other high-tech fields. Researchers transfer LED epitaxial materials to silicon, germanium, silicon carbide, copper and other substrates to prepare so-called thin-film LED chips to improve the photoelectric conversion efficiency of LED chips. The effective luminous surface of a thin-film LED chip is the top surface of the chip, so the upper electrode on the top surface of the chip is generally designed to contain several branches of the branching structure, and the surface area between the two adjacent upper electrodes is roughened to reduce the total reflection loss and improve the light output efficiency of the LED.
In order to improve the energy conversion efficiency and long-term stability of solar cells, the preparation of high quality and low-cost solar cell thin film has attracted much attention, such as nickel phthalocyanine (NiPc) thin film [5], perovskite thin film [6], antimuonium selenide (Sb$_2$Se$_3$) thin film [7] and other films have been widely studied recently. Solution deposition is the main way to obtain high-quality perovskite films. The basic film formation mechanism of perovskite films is a process of nucleation and crystallization, including nucleation, particle growth, Oswald maturation, condensation and so on.

Thin-film electrodes (TFEs) are a kind of electrode composed of a layer of nanometer to micron active material, which has been widely studied in the battery field. Its unique structure, as well as its thin and uniform thickness, not only ensures a fast response during charging and discharging but also allows TFEs to be used for portable or miniaturized devices. In addition, parameters such as operating voltage, cycle stability and self-discharge problems are equally important for practical applications of TFE-based batteries. The performance of thin-film electrodes is very important to the whole battery, so it is necessary to further study this aspect. There are many different types of thin-film electrodes, mainly including carbon-based TFEs [8], transition metal oxide (TMO) and conducting polymer-based TFEs [9], and emerging inorganic 2D material-based TFEs [10,11]. Turkoglu et al. reported the optimization of Zinc Tin Oxide/Silver/Zinc Tin Oxide (ZTO/Ag/ZTO) multilayers to implement them in thin-film solar cells as transparent electrodes. The performance was compared with ITO and AZO electrodes. The results show that the prepared multilayer electrode is a good choice for thin-film solar cells [12].

The development of science and technology and the progress of society are closely related to the research and development of new materials. Thin-film materials can be considered as a surface material, which is generally very thin and can be attached to the surface of the substrate. Thin-film materials have excellent mechanical and thermal properties, as well as photoelectric, piezoelectric, magnetic and other functions, so they are widely used in various production fields. Among them, thin-film materials are used in the field of photoelectric conversion and energy storage, which also greatly promotes the development of solar cells.

The preparation methods of thin-film materials are various. It mainly includes thermal evaporation, electrochemical deposition, atomic layer deposition, chemical vapor deposition, pulsed laser deposition and molecular beam epitaxy. Thermal evaporation [13] coating is a kind of physical vapor deposition (PVD) and a form of film deposition. It is a vacuum technology used to apply evaporation coating materials to the surfaces of various objects. Specifically, it refers to heating a solid evaporation material in a high vacuum chamber to reach the temperature of generating a certain vapor pressure, forming a vapor flow in the vacuum, impacting the substrate and forming a film to adhere to the substrate.

Electrochemical deposition [14] refers to the technology of depositing one or more layers of metal coating, alloy coating or composite coating on the surface of metal or non-metal parts. Generally, it is the cathode that places the device with a conductive surface in an electrolyte solution. Under the action of the external current, the metal ions or composite ions in the solution react with the reduction reaction on the surface of the workpiece, that is, the cathode surface, so that the metal is deposited on the surface of the device to form a thin film.

Atomic layer deposition [15] refers to the method of plating substances on the substrate surface layer by layer in the form of monatomic film. In this deposition process, the chemical reaction of a new atomic film is directly related to the previous layer. In this way, only one layer of atoms is deposited in each reaction, so the deposition layer formed by it has uniform thickness and excellent consistency. Its principle is that the vapor precursor pulse is alternately introduced into the reactor and chemically adsorbed and reacted on the deposition substrate to form a deposition film.

Chemical vapor deposition (CVD) [16] refers to the formation of thin films on substrate materials by chemical gas or steam, which is a traditional technology for preparing thin
films. Its principle is to decompose some components in the gaseous precursor through atomic and intermolecular chemical reactions and then form a thin film on the substrate.

Pulsed laser deposition (PLD) [17] is a method of bombarding objects with a laser and then depositing the bombarded substances on different substrates to obtain precipitation or thin films. It can be generally divided into four processes: the interaction between laser radiation and the target, the dynamics of molten material, the deposition of molten material on a substrate, and the nucleation and formation of thin film on the substrate surface.

Molecular beam epitaxy (MBE) [18] is a vacuum coating process. Its principle is that under high vacuum, the substance is heated to produce steam, which is collimated through the small hole to form a molecular beam and then directly sprayed onto the single crystal substrate to form a thin film on the substrate.

We have improved some traditional preparation methods more or less, but there are some shortcomings in this aspect. On the other hand, by combining the advantages and disadvantages of various processes, a new method for preparing thin films is designed.

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