

Solar Cells Fabrication Procedures

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Abstract: New energy is a very popular topic due to Global climate issues. Most countries propose to be carbon neutral and have their own plane. Solar energy as representative energy has attracted attention. Improving solar energy efficiency is an important research direction. The goal of this article is to determine that production process optimization efficiency. we will collect relevant data, compare and analyze, those processing methods. Since we need pure Silicon to make solar cells, our research will be from making silicon chips. Produce the silicon cells usually reduction and purification steps are needed to get pure silicon recovered from the impure Silicon Dioxide in quartz. This is often done by CAW and FTZ processes, and then put into polycrystalline silicon melt of the Czochralski growth apparatus. And cast it out from melt and pure cylindrical silicon is therefore produced. Cut off both ends of the ingot with a diamond saw, and then cut it into slices. Wafers are sliced from the crystal with diamond coated inside diameter (ID). This step determines the size of the wafer. Then mark 'flat area' or 'indent' on the slice to clarify the directions and make the following steps more convenient. Here we get the raw wafer, which has an uneven surface. To print circuit patterns on it, we go through grinding, chemical etching and polishing processes to remove surface defects, and form a smooth surface. Then we need to clean up the backside of the wafer. Normally, only the front side goes through the extensive CMP, so the backs may be rough. Backside will be recovered by sandblasting or deposition of the polysilicon layer on. After checking we have the meet the standard wafer. Due to the improvement of production technology, this article will focus on observing the improvement of solar panels by cleaning and doping steps.

1. Introduction

Solar cells are also called Photovoltaic, the name is from Greek. In English, it means light, volts and electrical. However, the name comes from Alexandrov who's in Italy. Also "Volt" is used as the unit of voltage after Alexandrov Volt.

Solar cells have entered a lot of areas such as industry, commerce, agriculture, communications, household appliances, and public facilities from the military and aerospace fields. It does not rely on electricity transmission lines from power stations and also can determine the size large or small by the power demand. So, it is more flexible. Especially the convenience of solar cells in remote areas, such as mountains, deserts, islands, rural areas and even space.

Solar photo-voltaic is a safe and reliable energy source that can provide relief from the increasing pollution and energy crisis. It is also more energy-efficient than traditional sources. Since the energy crisis in the 1970s, more countries have paid more attention to the development of photo-voltaic power generation. Some of these include the US, Japan, Germany, and China. Photo-voltaic Effect is a phenomenon that occurs when solar energy is used to generate electricity. This effect was first observed in 1839 by French physicist Edmund Becquerel. Current focus of solar battery research is on the development of efficient and thin film solar batteries. Thin-film solar batteries are more advantageous than traditional ones in terms of low-light effect and cheap. However, their biggest flaw

is their low efficiency. Solar cells are not only convenient to use but also important to environmental protection. As one of the important new energies, solar cells have no carbon or low carbon emission. So, when people use Solar energy, it's always with little impact on the environment. Also, Solar energy is very safe energy compared to some other new energy, such as Chemical energy, hydrogen energy and nuclear energy. The construction of human modern civilization is built on fossil energy, and traditional fossil energy not only brings prosperity, but also comes with a lot of problems. Such as global warming. However, the environment is not the only problem. The gas runs out, the coal runs out, these are problems that people often worry about. However, the solar energy is limitless energy, it is hard to imagine that humans have run out of solar energy.

Solar energy is very important, so what are solar cells? The solar cell is a device that converts sunlight into electricity. The solar cell is normally made of silicon. When the sun shines on the semiconductor p-n junction it can form a new hole-electron pairs. After the action of the electric field in the p-n junction, the hole which is made by light gone flows to the p-side, and the electrons will flow to the n-side, so a current is generated after the circuit is turned on.

Silicon solar cells are generally made of P+/N-type structure or N+/P-type structure [1]. P+ and N+ are shown the semiconductor material on the front side of the solar cell; N and P are the semiconductor material on the back of the solar cell. The electrical properties of solar cells are related to the characteristics, and the semiconductor materials which are used to manufacture the cells can influence the solar cells result.

2. Solar Cell Fabrication Procedures

2.1 Introduction

The continuous improvement of semiconductor processes has greatly impacted the profitability and reliability of electronic components. Improvement refers to the process of designing devices and circuits that feature smaller footprints and better reliability. The goal is to provide better performance and lower cost. The component dimension is typically expressed as the smallest part of a design. It is also referred to as the feature size. MOSFET is a type of transistor that is commonly used in today's technology. The gate is the controlling component of a system. It plays a crucial role in the production of high-speed and smaller circuits. Currently, the semiconductor industry is focused on the development of a 5-nanometer gate width. [3]

Four major general types of contamination are particulates, organic residues, inorganic residues and unwanted oxide layers. Each of the four contamination causes different problems, and each of them requires different processes to get re-moved. Purpose of spin-on application is to add layers on silicon wafer. Spin-on dopant application is to provide an impurity source for semiconductor junction fabrication. Dopant is first spread into substrate via spin-on dopant application and then diffused by a rapid thermal. [4]

2.2 Fabrication Procedures

2.2.1 Preparation of Semiconductor-grade Silicon from sand

This part explains the steps involved in the production of polished silicon wafers. It also provides a variety of information about the different types of silicon wafers used in the fabrication process. The challenges of preparing 450-mm wafers are discussed. The evolution of larger-scale chips has required the production of larger diameter wafers. [5]

Larger-diameter wafers are often necessary to accommodate increased chip sizes. The complexity of the preparation process and the need for high-quality equipment make it challenging to successfully produce these sizes. Wafer diameters larger than 300mm require more processing tools and are worth millions of dollars. [6] As the diameter of the microchip has grown, so has the need for more robust and time-consuming conversion to larger diameter wafers. This is one of the key factors that will continue to affect the evolution of the microchip.

Wafers are the surface area of a semiconductor material that is used to form devices and circuits. These components are typically formed in and around the silicon wafer.

Preparation Stages The first step in the process of making semiconductor materials is the purification of the raw materials. This step involves the use of a chemical reaction to purify the materials. [7] In this process, the ore is converted into a gas that contains silicon. The resulting silicon is then reacted with hydrogen. Silicon is a pure material that is Earth's purest. It has a crystal structure and is produced as poly-crystalline silicon. [14]

2.2.2 Materials

In materials, atoms are arranged in a certain way. For instance, in certain materials, such as silicon, their atoms have a definite structure. In crystals, these atoms are called crystals.

A basic atomic structure is achieved by placing atoms in a specific location within a particular frame. A material with a specific lattice structure can have both units arranged in a specific way. The number of atoms and their relative positions in a unit cell make a material different. Many of the characteristics of a material are influenced by its unit cell. The second level of organization refers to the arrangement of the unit cells within a crystal. In intrinsic semiconductors, these units are not in a regular configuration with each other. Organization occurs when the sugar cubes are neatly arranged relative to the other units. This level of organization allows the materials to have a single- or mono-crystal structure. A uniform and predictable structure allows for a high degree of stability and predictable electron flow in complex materials.

Aside from having a single-crystal structure, the orientation of a crystal is also required for the formation of solid-state components. This concept can be visualized by cutting a single-crystal block into various planes. Planes are defined by a series of three numbers, which are known as Miller indices. Two commonly used orientations are nested and one-one-one. The three numbers in the brackets '<>' indicate the number of Miller indices. These numbers refer to the orientation of the silicon wafers used for making metal oxide silicon (MOS) and bipolar devices. When the wafers are broken, they have orientations that are revealed. They can be broken into quarters or with a right angle.

Wafers are made from large crystals of semiconducting material. These are called ingots. Converting poly-crystalline chunks to a single-crystal structure is called crystal growing.

Three different methods are used to grow crystals: the Czochralski (CZ), liquid encapsulated Czochralski, and float-zone techniques [14].

1) Czochralski Method (CZ) crystal growth

Most of silicon crystals are produced by the CZ method. This process involves the use of a heated silica crucible. The crucible is loaded with various bits of poly-crystalline silicon and dopant material. The dopant is then selected to create either a N-type or a P-type crystal. After heated to the liquid state, the poly and dopants are placed on a seed crystal. [8] The seed is a small, spherical, and generally flat piece of glass that has the same orientation as the finished crystal. The surface tension between the melt and the seed causes the film to cling to the seed. As the temperature rises, the first atomic layer from the melted material orients itself to the seed's structure. The dopants from the melt then join the growing crystal. A feedback system is required to control the various factors involved in the process, such as the pull speed, the rotational speed, and the melt temperature. A crystal of 450-mm wafers will take about three days to grow. During the start of the growth process, a thick section is formed to support the larger crystal.

2) Liquid-encapsulated Czochralski (LEC) crystal growth

This process is commonly used to grow gallium arsenide crystals. It is achieved by liquid-encapsulating a LEC crystal with a high melting point and saturating it with arsenic. At the same time, the process produces a uniform crystal. Pressurizing the chamber can help prevent the evaporation of arsenic. This method is similar to the process of saturating a crystal-growing chamber. LEC is a process that uses boron tri-oxide to prevent the evaporation of arsenic. This method works by floating a layer of boron tri-oxide on top of the melt.

3) Float-zone crystal growth

Although the CZ method is commonly used for high-purity crystals, such as those used in medical equipment, the use of float-zone crystal growth is also applicable to special situations. This process involves casting a bar of polysilicon and dopants in a mold. The bar is then moved along its axis, heating it up to the liquid point. The atoms in each molten region align to the orientation of the

beginning seed. Since float-zone crystals can't produce the large diameter crystals that can be found in the CZ process, they are commonly used in semiconductor devices with lower oxygen content.

2.2.3 Environment Preparation

Devices with high-quality crystals require a great degree of precision to perform their intended function. Unfortunately, achieving a perfect crystal is not possible with most techniques.

NASA's space program established the basic principles of clean-room assembly for the semiconductor industry. However, the space program's constraints prevented the assembly of satellites in small rooms. The wafers were stored in boxes outside the workstations. The rooms were designed to prevent the wafers from getting dirty as they moved through the process. These filters are made of fragile fibers and have many small holes. The large area of the filter allows air to pass at low velocities. The low velocity helps keep the hood clean and the air flowing smoothly. A clean hood has a HEPA filter and a pre-filter. The air is drawn through the pre-filter and forced through the HEPA filter, which leaves a laminar pattern. The workstation refers to a type of vertical laminar flow station. This type of station is commonly used for air flow and chemical processes. It features a clean hood that's connected to the exhaust system. The station operates by taking advantage of the air coming out of the hood. It then uses a small positive pressure to prevent dirt particles from entering the work area. The VLF hood was also considered an inefficient method for controlling particulates. Also, it could have been contaminated by the many people moving about in the area. Instead of using individual ventilation hoods, these components are built into the ceiling, which serves as the same purpose. The trend has been to minimize the contamination of the wafer by restricting the air flow to the room. VLF hoods and tunnels have been used to isolate the wafer from the air. The larger rooms and tunnels of mines have the potential to contaminate the air with their massive volume.

The increasing costs for cleanrooms and the lack of return on investment prompted many companies to explore the idea of isolation of the wafer in small batches. This concept was already in use with steppers and other process equipment. The challenge was to create a series of mini environments that prevented the wafer from being exposed to the air. This concept was the basis for the standard mechanical interface. FOUPs (front opening universal pod) are de-signed to keep the wafers isolated from the environment. However, they can also be contaminated with chemicals that were previously used in the process. A robot-driven cassette-lifter can also be used to move the pod from the tool-wafer-to-wafer. The WIT allows for lower construction and operating costs. It also helps minimize air cleanliness, which lowers the overall pressure on operators. However, the addition of larger diameter wafers has raised the weight of the pods and requires robot handling. Systems can also zone off areas of varying degrees of separation from each other to prevent cross contamination.

Aside from controlling air pollutants, these parameters also have to be controlled in a cleanroom. The temperature control is also important for the operation of the equipment and for the control of chemical reactions. On the other hand, low humidity can create a buildup of static charge on the surface of the wafer. This charge can attract particles from the air. The primary challenge in the patterning process is controlling the amount of ozone that enters the air. This component can affect the development of the film. The selection of the clean air strategy for a cleanroom is the first step in developing a plan for keeping the facility clean. It is a trade-off that must be made between the cost of keeping a facility sterile and the benefits of keeping it clean. The inside of a cleanroom is made up of non-shedding materials that are suitable for use in applications. This includes wall coverings, floor coverings, and process station equipment. Every floor in a clean-room has an adhesive that pulls off and holds dirt particles on the floor. These components are attached to the shoes of the users. The gowning area is a part of a clean-room that is situated between the plant and the facility. It is commonly stocked with filtered air coming from ceiling HEPA filters. The operators use this area to change into their sterilized garments. It is the goal of the Clean-room Manager to maintain a high level of cleanliness in the area between the clean-room and the bench. This ensures that the facility is never contaminated. The bay serves as a semi-clean area for storing supplies and materials. It is placed into a clean-room through pass-through units that are designed to protect the cleanliness of the facility. Conductive materials with higher-density circuits are prone to contamination by static charge particles. This issue can affect the operation of equipment and the materials used to make them. The static charge

causes the particles to get stuck in the wafers and contaminate them. It is very difficult to remove these components with standard cleaning techniques. One becomes negatively charged as it gets electrons, while the other becomes charged as it gains electrons. Static is a device operational problem that occurs in devices with thin film layers. An ESD level of 10 A can destroy a device. This level of discharge can also destroy a circuit. In addition, photomasks and reticles are sensitive to ESD. This can cause a discharge to vaporize and damage the chrome pattern. Static issues with equipment are also common. The charge builds up on the wafers as it flows through the carriers. When it gets closer to the equipment, the charge dischargers interfere with the machine's operation. To prevent this, both preventive and counter-treating techniques are used.

Ionizers are used for air discharge. They are placed under the filter's HEPA, and they effectively remove any charge buildup in the air. They are also used on blow-off guns. Static discharge is also achieved by grounding operators with straps on their wrist. It is also done by grounding mats at critical stations and grounding work surfaces.

During the course of fabrication, a silicon wafer will be subjected to various cleaning steps, which are followed by a water rinse. The entire process consumes several hours of water-rinse systems. The dissolved minerals come from the salts in the water. They then break into ion-forming compounds. These are then re-moved through reverse osmosis and ion-exchange systems. The removal of these ions makes the water more conductive. This process also changes the pH level of the water. On the other hand, non-deionized water has a conductivity of 18 million-cm. Resistivity of the water is monitored at various points in the fabrication area. Water levels are also monitored at several locations. When fungi and bacteria find a favorable host in water, they are removed using ultra-violet radiation. Fecal materials and organic contaminants are removed using carbon bed filtration. The cost of cleaning process water is significant. Most fabrications require the use of meters to monitor the water used for cleaning. If the water quality is not maintained, it is discharged into the system.

The acids, bases, and solvents used in etch and clean water systems have to be of the highest purity to be effective. They should not be contaminated with metals, particulates, and chemicals. These chemicals are used in various applications such as semiconductor and electronics. They are generally too dirty for use in the semiconductor industry. The goal is to establish a uniform set of cleanliness standards for the industry. The primary issue is the metallic ion contaminants found in mobile equipment. Usually, these are limited to levels of 1 part million per million or less. Some suppliers make available chemicals with a MIC level of only 1 part per billion. An assay number shows the percentage of a chemical in a container. For example, if a bottle of sulfuric acid contains 99.9 percent, then it's clear that the acid is in the container. The proper handling and storage of a clean chemical is essential to its success. This process involves the use of containers that are not dissolved, as well as the use of particulate-free labels. Most companies buy bulk clean process chemicals in bulk. These chemicals are then distributed to the process station or into smaller vessels. The bulk chemical distribution system (BCDS) simplifies the process of dispersing clean chemicals. Regular cleaning of transfer and piping vessels is required to prevent contamination. One way to achieve this is by using point-of-use chemical mixers. These machines are equipped with mixing equipment that can be easily connected to a wet bench. The use of chemical pre-processors is also known as re-filtration. These units are placed on the drain side of a process station. The chemicals are then re-screened and reused. The process involves mixing the proper gases with water to make various chemicals. This method eliminates the need for packaging and transfer contamination. High purity is required for many process gases. These include oxidizers, etch, plasma etch, and diffusion. They are all chemical reactions that are dependent on an energy source. The highest purity is referred to as six 9s pure. This process involves maintaining the purity of the gas as it flows through a pipeline system. Outside air can also enter a process gas through a chemical reaction. This can change the composition of the gas and cause contamination of the system. Ultra-clean systems involve the use of polished or double vacuum melt-in-place surfaces to reduce out-gassing. They can also be made to feature oxygen passivation (OP). Clean welding processes are also critical to avoid the absorption of gases into the piping. Also, the control of water vapor is also important to prevent its harmful effects. Control of water vapor is necessary to prevent the accidental oxidation of silicon. This process can be performed by reducing

water vapor to 3 to 5 ppm. The air-separation gases are kept in the liquid state, which is usually cold. In the specialty gases section, they are kept in special cabinets outside the plant.

Wafers typically spend a lot of time in quartz holders. This is because it can be a major source of contamination. Particulates are produced by the scraping of the wafers in the process vessels and the scrapping of the furnace tubes. Knowing the sources of contamination is the key to successful contamination control. Most analysis identifies the process equipment as the biggest source of contamination. In the 1990s, the number of equipment-induced particulates increased to about 90 percent of all particle sources, which is not a huge change from the previous generation. As the complexity of equipment has increased, the focus has shifted to equipment defects. The number of particles added to a product pass is specified [14].

2.2.4 Cleaning Procedures

Big particulates can be removed by chemical bath and rinses. Small particulate matter is hard to remove which requires nitrogen blow-off guns to blow off the wafer and remove. To clean-up organic residues as oils in fingerprints, solvent baths are provided. Acetone, alcohol or TCE are general solvent for solvent baths. Inorganic residues such as inorganic acid, which includes hydro-chloric and hydro-fluoric acid are usually being removed by chemical cleaning or wet cleaning.

The above step requires an additional procedure to dry silicon wafer, how-ever it is hard to reach because of the water mask. Standard clean 1 (SC-1) uses a solution of water, hydrogen peroxide, and ammonium hydroxide. Standard clean-2 (SC-2) uses a solution of water, hydrogen peroxide, and hydro-chloric acid mixed. Particulate size on wafers varies from 1um to 50um. Big particulates can be removed by chemical bath and rinses. Small particulate matter is hard to remove because of capillary force and Van Der Waals force. To remove small particulates, we use nitrogen blow-off guns to blow the surface of the wafer. This often happened in Class 1/10 clean-rooms. Wafer Scrubbers are critical for particulate removal. The scrubbers hold the wafer on a rotating vacuum chuck. A rotating brush is brought in near contact with the rotating wafer while a stream of deionized water is directed onto the wafer surface. The combination of the brush and wafer rotations creates a high-energy cleaning action at the wafer surface. The liquid is forced into the small space between the wafer surface and the brush ends where it achieves a high velocity, which aids the cleaning action.

Another method used to clean the particulate is High-pressure water Cleaning. High-pressure water spray process is a small stream of ultra-pure water, which has a pressure of 2000psi to 4000 psi, so water stream with diastatic agent works together, and swept across the surface, and dislodging both large and small particles.

To clean-up organic residues as oils in fingerprints, solvent baths are pro-vided. Acetone, alcohol or TCE are general solvent for solvent baths. Inorganic residues such as inorganic acid, which includes hydro-chloric and hydro-fluoric acid. They are usually being removed by chemical-cleaning or wet cleaning. Different solvent can be chosen for wet cleaning. For wet cleaning, we chose Sulfuric Acid with Hydrogen Peroxide, because they are cheap and easy to get. Add 30hydrogen peroxide to the beaker in room temperature sulfuric acid. This reaction will raise the temperature, then wait till the temperature drops to the effective region. The above step requires an additional procedure to dry silicon wafer, however it is hard to reach because of the water mask. RCA Clean was founded by Werner Kern, it developed a 2-step process to remove organic and inorganic residues from silicon wafer. The first step, Standard clean 1 (SC-1) uses a solution of water, hydrogen peroxide, and ammonium hydroxide, the ratio we chose is 5:1:1, temperature is 80-degree Celsius. Standard clean-2 (SC-2) uses a solution of water, hydrogen peroxide, and hydrochloric acid mixed in ratios of 6:1:1, temperature of 80 degrees Celsius. SC-1 removes organic residues and sets up conditions for the desorption of trace metals, and SC-2 removes alkali ions and hydroxides and complex residual metals. The following cleaning step is to remove the Oxide layer. We use 49Hydrofluoric acid to soak over Silicon wafer.

Since Silicon does not react with Hydrofluoric acid so it is chosen to remove the oxide layer located on the top of silicon. Every cleaning step followed with a water clean process.

3. Result

Doping is the process of adding impurities to intrinsic semiconductors to alter their properties. We have a silicon solar cell that we want to dope, using the typical dopants boron (for p-type). Diffusion is basically the process of adding dopant to the silicon wafer to make it more electrically conductive. There are basically 2 methods of diffusion: solid state diffusion and emitter diffusion. [2]

4. Conclusion

Solar cells are not only convenient to use but also important to environmental protection. As one of the important new energies, solar cells have no carbon or low carbon emission. So, when people use Solar energy, it's always with little impact on the environment. Also, Solar energy is very safe energy compared to some other new energy, such as Chemical energy, hydrogen energy and nuclear energy.

The construction of human modern civilization is built on fossil energy, and traditional fossil energy not only brings prosperity, but also comes with a lot of problems. Such as global warming. However, the environment is not the only problem. The gas runs out, the coal runs out, these are problems that people often worry about. However, the solar energy is limitless energy, it is hard to imagine that humans have run out of solar energy.

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