Study on the toxicity of solar cells

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Abstract. A solar cell is a device that uses the photovoltaic effect to convert solar energy directly into electric energy. It is used in aviation, aerospace, transportation, communication, forestry and other fields. With the increase of solar cell materials in the environment, the potential impact on the environment is also increased. It has attracted wide attention. Solar cell materials mainly include multi-metal compound thin films such as cadmium telluride (CdTe), cadmium selenide (CdSe) and cadmium sulfide(CDS). Moreover, it includes nanocrystalline solar cell materials such as TiO2 and ZnO and molecular solar cell materials. The toxicity research status of solar cell materials was reviewed from three aspects: materials and organic solar cell materials. The development of this field is prospected.

1. Introduction
In this paper, the toxicity of solar cells is studied on the researches which were done by different scientists reviewed from three aspects: multi-compound thin-film solar cell materials, nano-crystalline solar cell materials and organic solar cell materials. At the same time, lots of problems are analyzed. How to affect the environment including animals and plants and how people should do become the problem. It is pointed out that solar cell materials will reduce the environmental risk from the source while it will also produce other troubles. To show the specific hazards of solar cells, next will introduce three components of solar cells that produce the toxicity influencing the environment by researches.

2. Environmental toxicity of multi-compound thin-film solar cell materials

2.1. CdTe thin film solar cells
CdTe is an n-vi compound semiconductor material, which has two kinds of crystal: cubic sphalerite and hexagonal wurtzite. The solar cell has the advantages of high photoelectric conversion efficiency, good stability, large light absorption coefficient, simple preparation method, and high stability. With the increase of the usage of CdTe thin-film solar cells, the environmental risk of environmental risk is also widely concerned.

At present, there are few studies on the toxicity of CdTe. Zhang Haixia[1] studied CdTe QDs by thermogravimetry. It was found that CdTe QDs could inhibit the proliferation of HL-7702 cells, cause DNA damage, affect the cell cycle process, cause s phase and G2 / M phase arrest, and induce apoptosis. Yu Qiuhong[2]found that after intravenous injection of CdTe QDs, the metabolism speed of CD and Te in blood was faster than that in the liver. The toxicity of CdTe QDs was related to its concentration. The results of total reflection Fourier transform infrared spectroscopy showed that the
outer cell membrane was damaged, which may make quantum dots or harmful by-products enter the cells and produce cytotoxicity.

CdSe has a wide range of applications in the field of solar cells due to its excellent size-dependent luminescence properties.

Figure 1. Model of CdTe thin film solar cells

Li Qingzhao and Hao Yulan[3] studied the effects of nano CdSe with different particle sizes on the liver and kidney function and testis of mice and found that the smaller the particle size of CdSe nanoparticles, the greater the damage to liver, kidney and testis of mice. The effect of particle size on the toxicity of CdSe was consistent with that of CdTe.

On this basis, the researchers further explored the toxic mechanism of CdSe nanoparticles in the organic body. It is related to the enhancement of membrane permeability.

2.2. CdS thin film solar cells

CdS has a wurtzite structure and is well absorbed in the visible light range, so it has become the focus of attention.

Li Yunrui[4] studied the effect of nano CdS on different cells were detected and mRNA expression. It was found that the toxic effects of these substances on aquatic organisms and vertebrates are obviously different, and the effects of Te on the immune activity of rats and mussels were also different.

CdS are toxic to animals, plants, and microorganisms in the environment. CdS was modified in order to reduce its environmental toxicity from the source. The effect of the modification of CdS on the activity of cysteine was also studied. The toxicity of CdS decreases, which is related to the properties and particle size of the surface modifier.

2.3. GaAs thin film solar cells

GaAs is a typical III-V compound semiconductor material with a direct band gap width of 1.42 EV. As a result, GaAs is an ideal solar cell material.

Studies have found that exposure to GaAs can cause acute and chronic toxicity to the lungs, reproductive organs and kidneys of animals. Because of the low solubility of GaAs, more attention should be paid to chronic toxicity.

3. Environmental toxicity of nanocrystalline solar cell materials

3.1. environmental toxicity of TiO2

TiO2 is a kind of n-type wide bandgap semiconductor material with stable physical and chemical properties.

In particular, it has unique photophysical and chemical properties such as photoelectric conversion, photochromism and photocatalysis. It is an important part of dye-sensitized solar cells.[5] However, when the adsorption energy of TiO2 is greater than the bandgap, ROS will be produced when it is
wide, and ROS will contact with living organisms such as animals, microorganisms and plants in the environment. It will have an impact on their life activities.

The environmental toxicity of TiO$_2$ is affected by its particle size, surface properties, crystal structure and other internal factors.

The toxic effects of Nano-TiO$_2$ on organisms in the environment have been widely studied, including animals, animals, and so on. Researchers have also done a lot of research on the influencing factors of its toxicity.

However, the mechanism of toxicity in organism is not clear, and there is no effective detection method to support the toxicity.

![Figure 2. TiO$_2$ photocatalyst](image)

### 3.2. Environmental toxicity of ZnO

ZnO is a new type of hexagonal wurtzite structure of direct bandgap II-VI semiconductor material, which has a low price, low cost, abundant reserves and excellent photoelectric performance, widely used in the field of solar cells.

![Figure 3. The structure of ZnO](image)

Studies done by Giovanni and Du[6] prove that Although the environmental concentration of these nanoparticles is lower than the threshold concentration which can cause toxic effects on organisms, they may produce cumulative toxic effects after accumulating in organisms.

### 4. Environmental toxicity of organic solar cell materials

Organic solar cell materials have the advantages of small bandgap and large light absorption coefficient. Common organic solar cell materials include fullerene, phthalocyanine, hypophthalocyanine, porphyrin, cyanine, perylene and other small molecules, as well as organic
macromolecules. At present, the toxicity of organic macromolecular solar cell materials is rarely studied. Only a few studies have been reported on the environmental toxicity assessment of organic small molecule solar cells such as fullerenes. And the fullerenes have low recombination energy and high reduction potential. The performance and efficiency of photovoltaic devices are greatly improved by accelerating photo induced charge transfer and effectively restraining electron return rate. However, in recent years, with the application of fullerene in solar cells more and more widely, its environmental toxicity. Cytotoxicity was associated with increased intracellular flux and mitochondrial perturbation in raw 264.7 cells. Some scientists discussed the effects of fullerene on the cat, GSH PX and SOD in human embryonic hepatocytes. The effects of fullerene on the expression of cat, GSH PX and GSH PX in human embryonic hepatocytes were observed.

5. Suggestion
Although solar cell materials are toxic to the environment in many ways, there are some ways to improve this situation. Firstly, because the toxicity mechanism of each solar cell material is different, it is an effective solution to produce environment-friendly solar cell materials. This will reduce environmental risk from the source. Moreover, when traveling, reduce the use of vehicles and other devices that require solar cells. In some ways, it reduces the harm of solar materials.

Solar cell materials are convenient in many aspects of our lives. For example, people tend to choose hot water heater to save electrical energy. Moreover, a large number of falling film evaporation solar desalination units were designed to improve the environment. Then a problem comes, how to reduce the harm of solar cells. From my perspective, it is necessary that exploring new environmental protection energy which could reduce the use of solar cells basically and at the same time, trying to reduce the harm of solar cells by some technical means.

6. Conclusion
In recent years, with the rapid development of the solar cell industry, the environmental hazards caused by solar cell materials are becoming more and more serious. The research on harm is also increasing. At present, the research on the toxicity of solar cell materials mainly focuses on multiple aspects. Compound thin-film solar cell materials and nanocrystalline inorganic semiconductor solar cell materials, while related to organic small molecule solar cell materials, organic macromolecular solar cell materials, and new organic metal halides. The environmental toxicity of perovskite solar cell materials is relatively less. The research objects are mainly animals and microorganisms. Plants, such as wheat, corn, and soybean, are closely related to people's life. The main targets of the animals are zebrafish, earthworm and rats. The main test indexes in the microbial experiment were carbon mineralization content and bacterial abundance. Plants mainly measure their effects on photosynthesis. In the current research about solar cell materials, the transport process in the organism and the mechanism of toxicity are not clear, and the second exposure is not considered. The further study of toxicity mechanism will be the environmental toxicity research of solar cell materials. It is helpful to further assess the environmental risk and guide the design of environment-friendly sun energy battery materials, from the source to avoid environmental risks.

Acknowledgement
First and foremost, I would like to show my deepest gratitude to my team members and professor Xie in this program, who have provided me with valuable guidance in every stage of the writing of this thesis. Further, I would like to thank all my friends and family members for their encouragement and support. Without all their enlightening instruction and impressive kindness, I could not have completed my thesis. Moreover, I have learned a lot about semiconductor from this program besides solar cells. I become interested on these aspects so that based on this knowledge learning on the class, I search lots of information of toxicity of solar cells on the Internet. And that is the reason why I write this essay.
Reference

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