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PRODUCTION METHOD OF RENEWABLE ENERGY TOOLS: SMALL SIZED SILICON-BASED SOLAR CELL

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Abstract
The need for the new sources of energy has been rising progressively considering the growing demand. It is well-known that fossil fuels will not be used continuously to compensate all demands of energy. Thus, the renewable ones must substitute for fossils. Among renewable energies, solar energy was selected as the research topic being a major option. The main reason behind the study is to show an alternative method of creating new-generation cells. As the content, it was aimed to manufacture a solar cell and, it was achieved for the size of 2x2 cm by the following methods which determined processes as a result of the examinations. P-type silicon was selected as wafer due to its contribution to high total efficiency. After getting this material as p-type, phosphor was determined from 5A group in order to create p-n junction and it was diffused inside in the high temperature levels. Because in only this circumstance, solar energy mobilizes the idle electrons in the material and subsequently, it is provided to fill orbitals where they belong to. After forming p-n junction, anti-reflective coatings (ARC) were implemented to the surface so that much more electrons to flow in the path. Then, the strips were built up the both sides of this mat to complete the equivalent circuit diagram. Consequently, metallization processes ensured to obtain the highest level of voltage. For the up-side, Ag was chosen due to its good value of conductance. During all these processes; XRD, SEM, and Reflectometer machines were used to test the material. According to results, this technique, as separately each section of the study, can clearly be selected as a production method for larger sized solar cells.

Introduction
Renewable energy is a type of energy obtained from energy flow that is already exist in the natural process of the world. These energies can be categorized as solar radiation, wind, flowing water (hydro power), geothermal and biological processes. Generally, it is assumed that this type of energy can refresh itself in a faster way than the source consumes itself or at least equally. For instance, when it is thought the technology working by consuming this energy comes from the sun, this consuming energy is at very low level compared to the total solar energy. Theoretically, despite the fact that fossil fuels are also able to be named as renewable during the period of habitats life time, it is probably going to be extinct due to usage at this velocity. The World Energy Forum has predicted that fossil-based oil, coal and gas reserves will be exhausted in less than another 10 decades. Fossil fuels account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are diminishing rapidly (Kumar, Kumar, Kaushik, Sharma, & Mishra, 2010).[4]

Solar photovoltaic energy conversion is based on the conversion of light energy into the electrical energy. The light is composed of quantized energy packets called photons, whose energy is stated by the frequency or color of the light. To obtain an electrical energy, one needs the flow of free electrons and holes created by the light energy. In a photovoltaic device, the electrons absorb the energy of photons and are excited to the conduction band, where they are nearly free to move.

Maximum Power Point (MPP)
Maximum power point represents the maximum power obtained by multiplying the current and the voltage over the load under a certain amount of light. On this point named as MPP, the current and the voltage are also

named as MPP current (I_{mpp}) and voltage (V_{mpp}) of the photovoltaic cell. There are different MPPs for each amount of light.Figure3.demonstrates how MPP is defined with the points of V_{oc} and $I_{sc.}$[8]

$$MPP = V_{mpp} .I_{mpp} \quad [mW] \qquad (1)$$

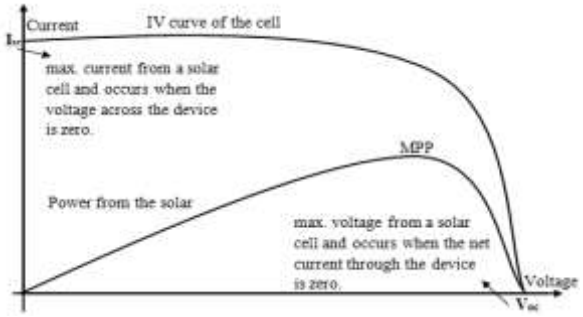


Fig.1. I-V characteristic showing how MPP occurs in the cell

Material & Method

The aim of the thesis is to develop silicon-based solar cells which are new and domestic production regardless of looking the cost as a production process used in all areas. Another important aspect of the thesis, the used silicon interior layer is in a mono-crystalline type, able to be found easily, has higher efficiency and now can be produced in our labs. From this point of view, in this research, the new approach is to explore both the science and technology of how source of dopant affects the output efficiency as p-n junction and connect the results to materials properties, show the engineering concepts that can be used to produce or improve silicon-based materials techniques. Commercial p-type Si was selected as wafer having been already doped with boron previously, which is one of 3A group elements of periodic table in order to build holes inside the p-n junction inside the cell. To start with, surface finishing process was applied to wafers through the liquid compounds such as Al_2O_3, SiO_2 and CeO_2. During the surface process, sticker material was used between the wafer and the head of compressor in order to keep it tight. Acetone (C_3H_6O), hydrochloric acid (HCl),hydrofluoric acid (HF) and pure water (H_2O) was the last materials have been used respectively to sterilize the wafers before the main processes such as doping and coatings. After this sterilization, samples were doped with phosphoryl-chloride ($POCl_3$) in the high temperature oven. Then ARC process was applied by helps of coating TiO_2 and Al_2O_3 targets over the samples. For the back side of the wafer, aluminum folio was selected and small globe shaped Ag was used to make up the front side lines.

In the beginning, samples were finished over the surfaces and cut into 2x2 cm sized small pieces in order to take them into chamber of the next machine. Then by helps of a spin coater device, the front surfaces of the samples were filled by liquid form of diffusion material. Consequently, samples were taken into the machine working as high temperature oven. After that the samples were applied to coating process which would decrease the reflectance of the sunlight in the visible form. Finally, back and front contacts were built for electrons in order to complete their flow and measurements were noted with one and total number of cells.[7]

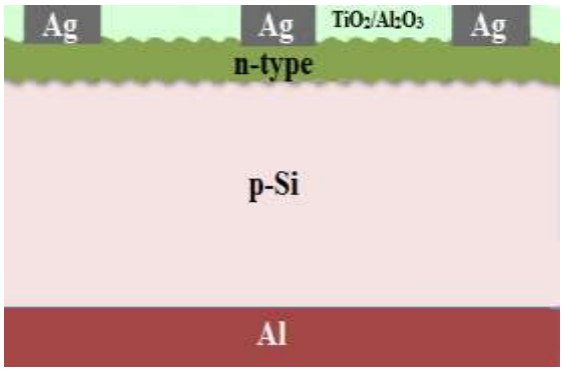


Fig.2. Schematic picture of the photovoltaic cell

Diffusion process, as the one of the key processes of the thesis was conducted by the study of Crisp, (2010), with the following temperature evalues showed in theTable1.[2]

Table 1. Recipe for diffusion process

Temperature	Time
200 °C	5 min
400 °C	10 min
900 °C	2 min

Result And Conclusion

TiO_2 can be seen perfectly from the view of top of the sample as graphically seen in the Figure 3. The working area of the sample was selected randomly a few times and the coating was analyzed by XRD. It should be noted that, as a result of this analysis, TiO_2 coating was determined obviously. This result clarifies the structure of the coating and the amount of substratum material in the surface is very low in the samples, their XRD patterns were not detected clearly.

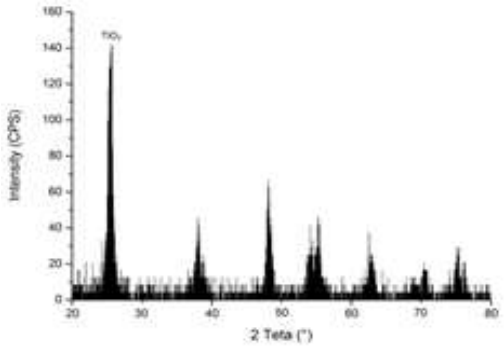


Fig.3. XRD analysis after ARC coating TiO_2 heading on top

It can be seen that only the tail part of the diffusion experiences an enhancement. The results also showed that there is no diffusion zone for electricity before the process which led to flow of electrons. This also proved that there are nearly any other particles having occurred during the other processes or before the diffusion. As it is seen in the Figure4, p-n junction zone can be selected clearly after doping phosphorus inside the p-type silicon wafer. This means the flow of the electrons is possible by building n-type layer over the p-type material.

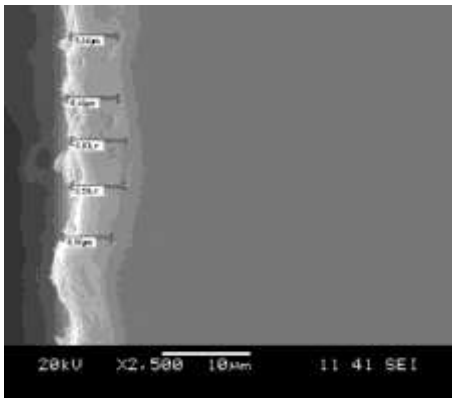


Fig.4. Scanning Electron Microscopy results after doping n-type material with measurements

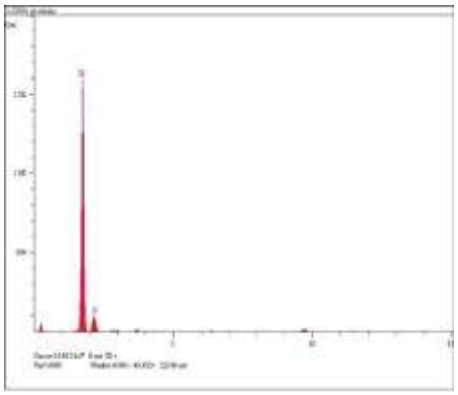
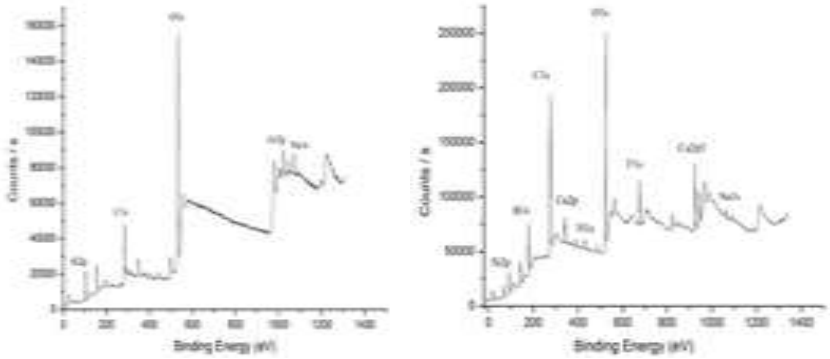


Fig.5.Scanning Electron Microscopy analysis including Phosphor diffusion over the sample

Total concentration of Si has inside the wafer 99.026% while P has only 0.974%. This might be seen very low percentages for P, comparing to Si has. However this value is even more than adequate concentration that is needed to make up the p-n junction. These values can be also stated as molar concentration, by this way Si has 99.116% in all wafer while P has 0.884%. This change arises from the difference between molecular weight of two elements, Si and P.



(a) ***(b)***

Fig6. Result of (a) pure Si wafer surface (b) p type doped Si with Boron

These two analyzes were made in order to compare if there is any deference between the wafers doped and pure. Results showed that p type Si wafers are clearly seen in the graph focusing the bottom corner part due to atomic

weight of boron which have only 5. On the other hand, the other type of wafer that is never used in the process hasn't shown any presence in the Figure6. (a) conversely seen in (b).

In this thesis, one of the key analysis was reflectometer analysis due to the fact that it measures the most effective method performance, anti-reflective coating. These type of coatings make cells less reflective. Thereby the sunlight come from the sun is used in a more effectively way than it was before. The results proofed that ARC process has been applied correctly as it should be. As it is seen in the Figure7., the mean of the reflectance of the material has been considerably changed showing different reflectance percentages at different wavelengths especially between 500 and 600 values of λ. Visible light that ensures us to see the objects is between 400 and 700 as it is known. And here is the comparing graphics below including three different circumstances.

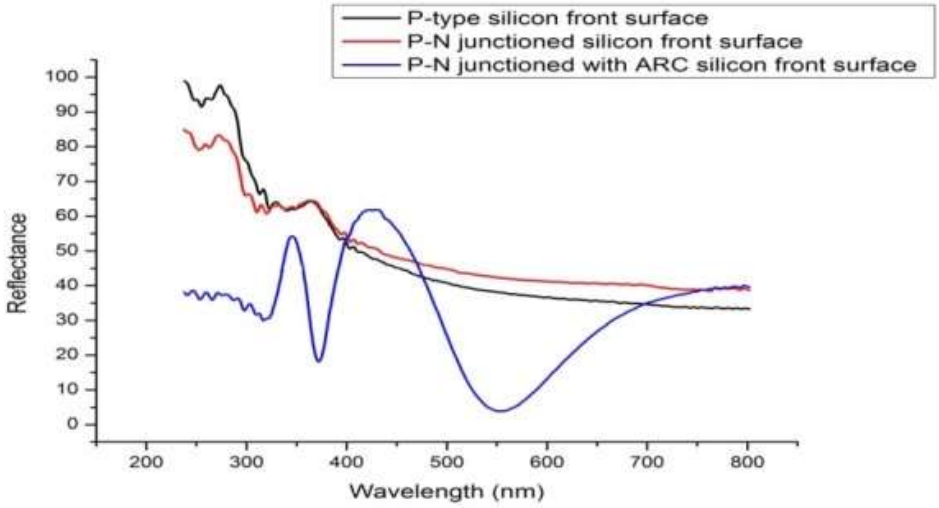


Fig.7. Superiority of ARC among the sample surfaces

After the all sections, there had a chance to evaluate or see the results. Plus (red one) probe was connected to the n-type region over the one of the strips, the other prop (black one) was connected the other region which was at the back surface coated by Al.The first trial was conducted in the daylight. The variable values were between the interval 300-400 mV. The following measurement was made again under the sunlight. However, this time there were three cells connected to each other which have same production method property. As it was expected, in these conditions there was same attitude from everyone, there of them produced almost the same value of the voltage. Totally, 1.0484 V potential differences were recorded from three of them.

Fig.8. Total voltage amplitude of three small sized cells

The results and studies roughly show that it is possible to produce a silicon-based solar cell around these efficiency levels. World energy requirement is still mostly obtained from fossil energy sources. Apart from the fact that these sources will be extinct in the near future as it was told in the content previously. The prevention effort of environmental problems, caused by the consumption of fossil fuels, forces countries to evaluate their energy sources and to use existing sources more efficiently. Adverse impacts of the use of indispensable energy sources for the existence of humanity require more careful and planned actions. Although this issue was only for the study subjects of universities until last a few years, nowadays is getting common in public. In all over the world, environment consciousness ensures to use the energy sources in a more and more efficiency way. Thus, these kinds of productions should be encouraged in a much deeper way by the governments. However, there is no much time to catch this trend in the world since developed countries have already begun to compete with each other lots of years ago.

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