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What Are Photoresistors and How Do They Work

Photoresistors allow us to sense the world around us and really understand how different particles can interact with and affect different materials. Specifically, photoresistors are light dependent electrical resistors. An electrical resistor is an electronic component that resists the flow of electricity and is measured in ohms. Think of electricity as water flowing through a pipe, where the electrons are water molecules. Now if there were to be a kink in the pipe, that would restrict/resist the flow of water. So, the smaller the resistance, the more flow of water is achieved, and vice versa. It's almost the same thing for electrical resistors. Simply a longer piece of copper wire could act as a resistor. This is because every metal has an electrical resistance. Copper however has a lot less. But still, a longer piece of wire would have more resistance. The electrical resistance is given by the formula, $R = V/I$ (you could also use this to calculate the current, $I = V/R$) where the R stands for resistance, V is voltage (electrical potential measured in volts or the pressure of water), and I is the electrical current [5]. Electrical current is the number of electrons in motion (like the number of water molecules flowing in a pipe, to keep with our water analogy) and is measured in amps [5]. One amp physically means that 6.24×10^{18} electrons are flowing in a wire per second [5]. So, according to the resistance equation, the higher the current, the lower the resistance (and vice versa). And in somewhat the same way, photoresistor use chemistry and light to change their resistance to electricity and since photoresistors are just *Light Dependent Resistors*, they're also called LDR's (which's how it will be referred to for the rest of this paper) [3, 4]. It all depends on how much light hits the sensitive face. But how do they work? And why do the materials they're made of act in this way?

In general, photoresistors are made of high resistance semiconductors such as silicon or germanium [4]. And the most common are made of cadmium-sulfide (CdS) [6]. However, LDRs are also classified into two types, depending on the materials used to make them: Intrinsic photoresistor and Extrinsic photoresistor [4, 3]. In simple terms, intrinsic photoresistor are made of pure semiconductor materials like silicon and germanium [4]. Both Silicon and Germanium have four valence electrons and once they form a covalent bond (they share electrons) with their neighboring four atoms (as seen in Figure 1), their valence band is full of eight electrons [4]. Once light energy is applied to the Intrinsic LDR, only a few valence electrons gain enough energy and become free from the parent atom, thus small current flows. And since the current increased a bit, the resistance decreases a bit in the Intrinsic

LDR. Hence, Intrinsic LDRs are less sensitive to light and are less suitable for practical applications [4].

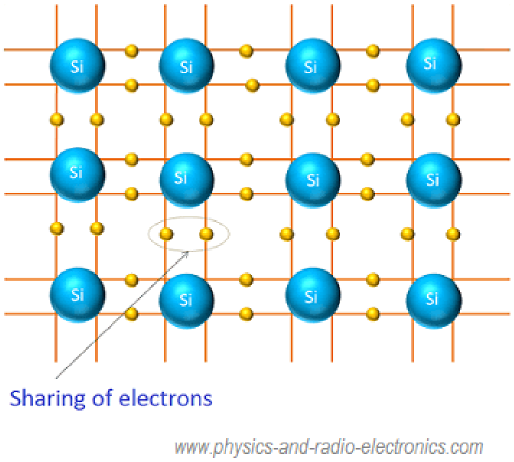

Figure 1

Extrinsic photoresistors are made from extrinsic semiconductor materials (i.e., silicon and phosphorus) [4]. In the example of silicon and phosphorus, each silicon atom has four valence electrons, and each phosphorus atom has five valence electrons. So, once the silicon and phosphorus form covalent bonds, there is an extra electron from the phosphorus atom (Figure 2) that cannot bond with silicon because silicon has only four valence electrons [4]. Hence, each phosphorus atom generates a free electron. This free electron will collide with nearby valence electrons of atoms and make them free [4]. So, just a few free electrons from phosphorus make millions of free electrons [4]. These free electrons act as charge carriers (carry an electric charge) and when light energy is added, even more charge carriers are present, thus the electrical current increases rapidly [4, 3]. And the higher the current, the lower the electrical resistance (the electrical resistance is inversely proportional to the amount to light). So, by applying light to extrinsic LDRs, the noticeable change in resistance can be achieved, thus extrinsic photoresistors are more fit for practical applications than intrinsic photoresistors are.

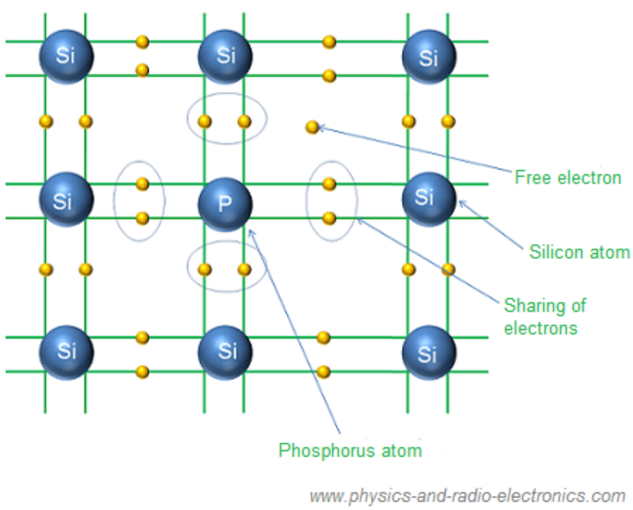

Figure 2

Photoresistors are used in a variety of different applications. For example, they are used to detect the nearby light levels so that streetlamps know when to turn on and off, automatically. They can also be used in household devices like night lights and alarm devices. However, they do have their drawbacks. Photoresistors are less sensitive than photodiodes, the common material they're made of (Cadmium Sulfide) is hazardous to the environment, they have slow response times (from 10s to 100s of milliseconds), they're sensitive to temperature changes, and have non-linear characteristics [7].

Research has been done on how different materials can also act as photoresistors. For example, carbon nanotubes (CNTs) are considered as one of the excellent nanostructures, due to their one-dimensional nature and electron transport properties [1]. Photocurrent of single walled carbon nanotube (SWCNT) films and optical studies on freestanding transparent films, together with their unique density of states present, allows them to produce electron-hole pairs when exposed to electromagnetic radiation [1]. These electron-holes will change the electrical resistance, essentially acting like an LDR. Furthermore, the CNTs showed polarization selectivity, ultraviolet absorption, and infrared detection due to their characteristic electronic structure [1]. Because of these behaviors exhibited by CNTs, they're used in different electronic applications like in field effect transistors (FETs), transparent conductors, ring oscillators, supercapacitors, sensors, etc. [1]. Also, due to the physical properties of CNTs, for the first time, foldable photoresistors can be developed [1].

Furthermore, researcher Qingyu Chen and his colleagues researched the integration of multiple functional devices to achieve complex functions. This device is composed of a biocompatible organic polymer resistive-access memory (RRAM) and a photoresistor for wearable image sensing applications [8]. This organic polymer RRAM is composed of polychloro-para-xylylene (parylene-C) which is both flexible, transparent, and biocompatible [8]. This multi-functioning device detects the light intensity and simultaneously stores that information in the memory device for wearable image sensing applications [8]. Also, this organic RRAM shows switching properties, low operating voltages, high storage window and good retention properties [8].

Works Cited

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