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PHOTOVOLTAIC MICRO-CELL DESIGN FOR DISTRUBUTED POWER IN SENSOR NETWORKS

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Abstract: We present a new study of power over optical fiber, for use in optical fiber smart sensor networks, using silicon-based photovoltaic micro-cells. A number of parameters in the design of the micro-cell for implementation in a power converter chip have been investigated. Matching the beam profile to the active region, as well as maximizing the contact area improves the device efficiency. The effect of doping profile and junction type on the device performance, suggests silicon is a cost effective and suitable material for this application.

1 Introduction: Research on III-V material photovoltaic power converters, (PPC's) usually complex heterostructures involving GaAs or InP, has shown optical power conversion as high as 50% [1]. Terrestrial solar cell development for high power applications using silicon-based cells has also indicated high efficiencies for these types of solar cell structures for monochromatic illumination [2]. Here, we suggest a novel idea of coupling a silicon photovoltaic micro-cell to an optical fiber for use as a PPC. Silicon, although not the most efficient optical power converter, is suitable for this application because of its high responsivity between 600nm and 900nm, as well as its obvious low cost of fabrication.

In this paper, we present the results of a study to optimize the power output of a silicon-based pn junction photovoltaic micro-cell for monochromatic optical fiber illumination. The effect of a number of device structure and material parameters have been simulated and optimized, so that a dedicated PPC chip can be used to meet the power budget of a distributed optical fibre smart sensor system currently being developed. All of the results were obtained using an incident optical power of 100mW, so that the output power equates to efficiency.

2 Results: Fig. 1 shows a graph of device thickness against incident wavelength and the corresponding maximum efficiency.

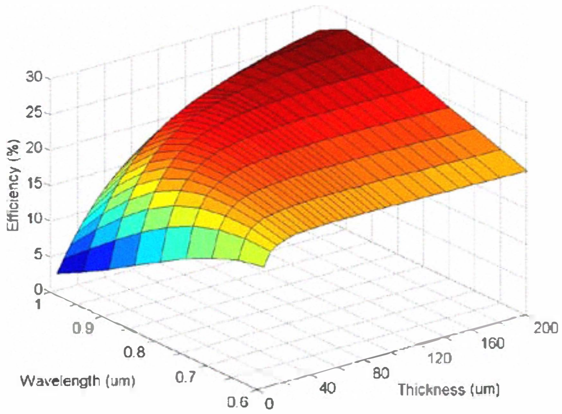

Fig. 1: Maximum efficiency for device thickness against wavelength.

Fig. 2 shows a logarithmic graph of wavelength against thickness. The equation can be used to predict the optimum thickness for a given wavelength, i.e. the optimum thickness for a wavelength of 980nm is approximately 265um.

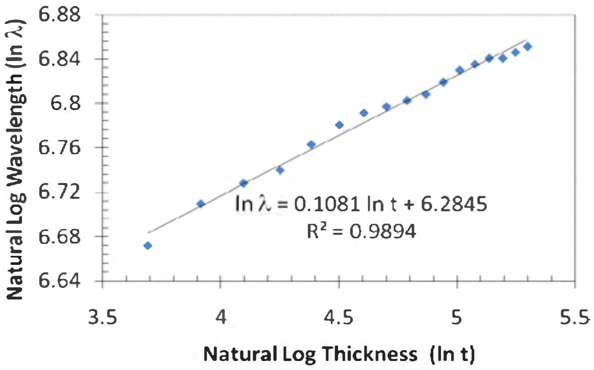

Fig. 2: Logarithmic graph of wavelength against thickness.

Shown in Fig. 3 is the relationship between wavelength and output power for various beam widths. The optimum beam width occurs at 300um, the same width of the emitter region.

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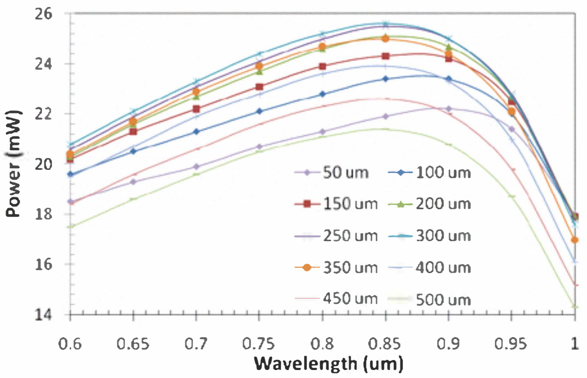

Fig. 3: Maximum output power against wavelength for various beam widths

Fig. 4 and Fig. 5 show the effect of both the emitter and base doping concentrations on output power for a p+n device and a n+p device, respectively.

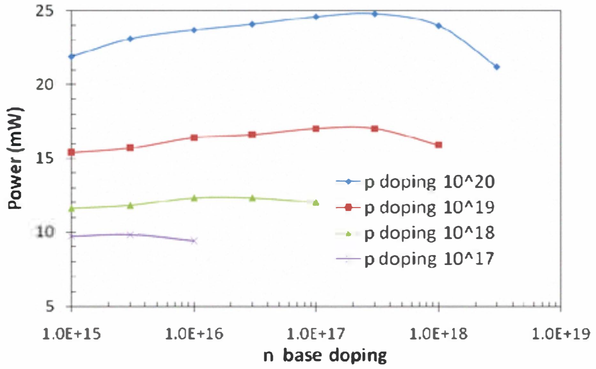

Fig. 4: Maximum power against n doping concentration for various p doping concentrations in a p+ n device.

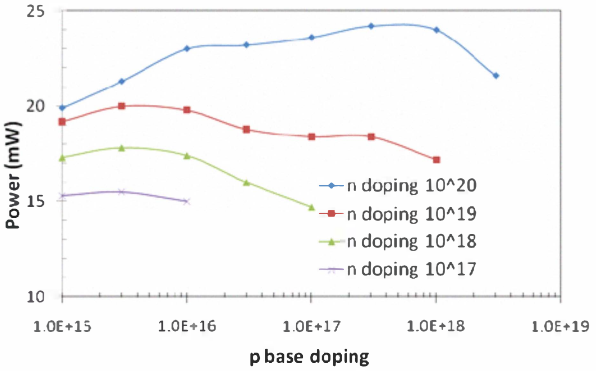

Fig. 5: Maximum power against n doping concentration for various p doping concentrations in an n+ p device.

The n+p device performs better at lower emitter doping concentrations because the mobility of the minority carriers, electrons, is higher than that of the p+n minority carriers, holes.

A consideration was made to increase the size of the anode so that it was the same width as the emitter region. This improved the collection of carriers considerably and therefore improved the efficiency. Finally, using the results from all of the previous considerations, the I-V characteristic of the most theoretically efficient PPC, producing the maximum output power, was simulated. Table 1 shows the parameters used in this simulation, and the corresponding output characteristics. The corresponding I-V curve and power curve are shown in Fig. 6.

Table 1: Device parameters.

Parameter	Value	Units
Beam width	300	um
Wavelength	850	nm
Base n-doping	$3x10^{17}$	cm^{-3}
Emitter p-doping	$1x10^{20}$	cm^{-3}
Short circuit current	62.5	mA
Open circuit voltage	0.78	V
Fill factor	81.2	%
Output Power	39.6	mW

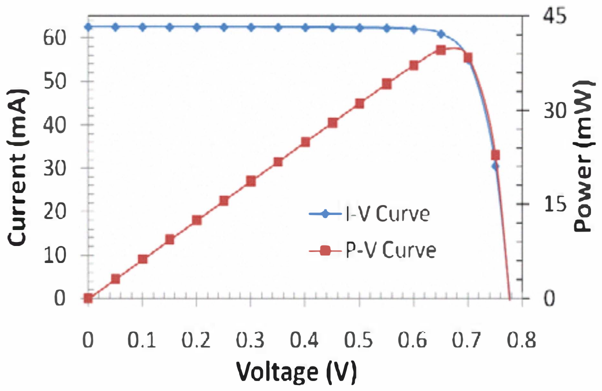

Fig. 6: I-V curve and power curve for the optimum designed silicon PPC.

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