Fabrication of a light detector using semiconductor material

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Abstract

A light detector will be fabricated by evaporating a thin metal layer onto the substrate. Current will be passed through the light detector and the I-V will be measured. From the result of the experiment, comparison can be made between different combinations of contacts, light intensities and substrates. GaAs and silicon will be used as the semi-insulating substrate. Besides, gold and aluminium will be used as the contact.

Introduction

Photo-detector can be made in various semiconductors. For example, Ge, Si and III-V compounds and their alloy. We select a particular semiconductor because of their difference in quantum efficiency at a particular optical wavelength, the response speed and the noise.

a) Germanium avalanche photodiode have high efficiency at wavelength 1 to 1.6μm.
b) Silicon avalanche photodiode have high efficiency at wavelength 0.6-1.0μm.
c) Metal-semiconductor (Schottky-barrier) avalanche photodiode work well in Visible light and ultraviolet range. The characteristics of Schottky-barrier avalanche photodiode is just like p-n junction photodiode.

Hetero-junction avalanche photodiode (e.g. AlGaAs/GaAs, AlGaSb/GaSb) have many potential advantages over Ge and Si device.

(1) By adjusting the composition, the response wavelength can be change.
(2) Because of the high absorption coefficient of the direct–band gap III-V alloys, the quantum efficiency can be high even if a narrow depletion width is used to provide high-speed response.
(3) Furthermore, the hetero-structure window layer (larger band gap) is grown to provide high-speed performance and minimize the surface recombination loss of photo-generated carries.

In this experiment, we deal with visible light. The Schottky-barrier avalanche photodiode is the aim of our study.

There are a lot of factors, which can affect the light detectors. In the study, we have considered the factors including the intensity of light, the metal contact and the substrate (GaAs and Si respectively). Comparisons between different elements were made in this study.

Experimental

The procedures of the experiment:

1. Chemical etching

First the GaAs samples were rinsed in acetone and methanol for degreasing and then rinsed in deionized water. Then the samples were etched in the solution NH_4OH: H_2O_2: H_2O, with ratio (3:1:90) for one minute followed by a deionized water rinsing. After that the samples were then etched in the solution H_2SO_4: H_2O_2: H_2O, with ratio (8:1:1) for another one minute. Finally the samples were rinsed in deionized water for two minutes and put into the vapourization chamber after drying .

2. Vaporization

Metal wire had previously been cut into small pieces and put on the tungsten filament evaporation source. The chamber was then immediately pumped down 10^{-6}Torr, to reduce surface oxidation of the sample. The system took almost an hour to pump down to 10^{-6}Torr, at which pressure the evaporation was started. The evaporation was carried out by passing a large current through the filament so as to vaporize the metal, which deposited on to the surface of the sample as the contacts.

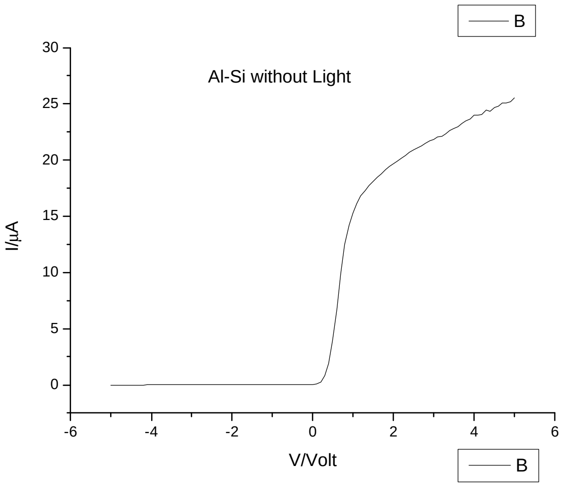
3. Measurements

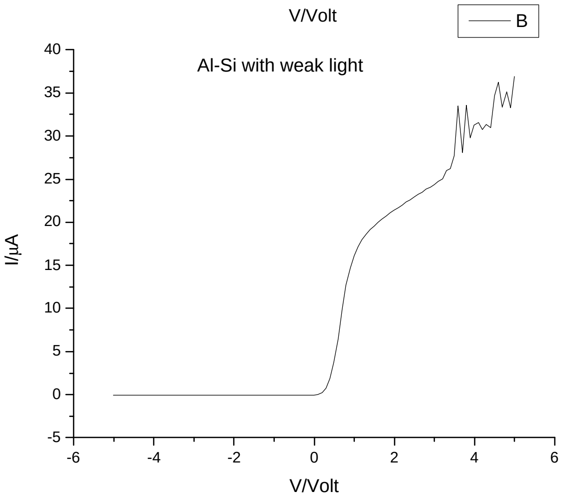
Silver paint was used to link the contacts of the sample with a stand by means of very thin wires. The stand is connected to the semiconductor parameter and I-V was measured.

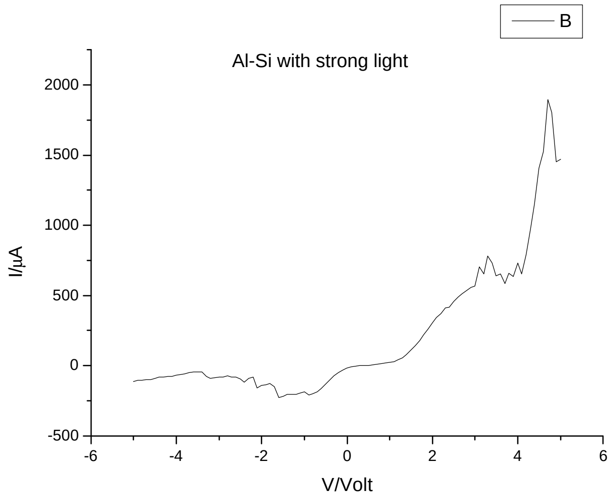
Result and Analysis (the comparison between different elements affecting the light detector)

1) Results of I-V measurement by curves
2) Comparison between different elements by tables

Graph 1 I-V curve of silicon substrate with aluminium and gold contacts



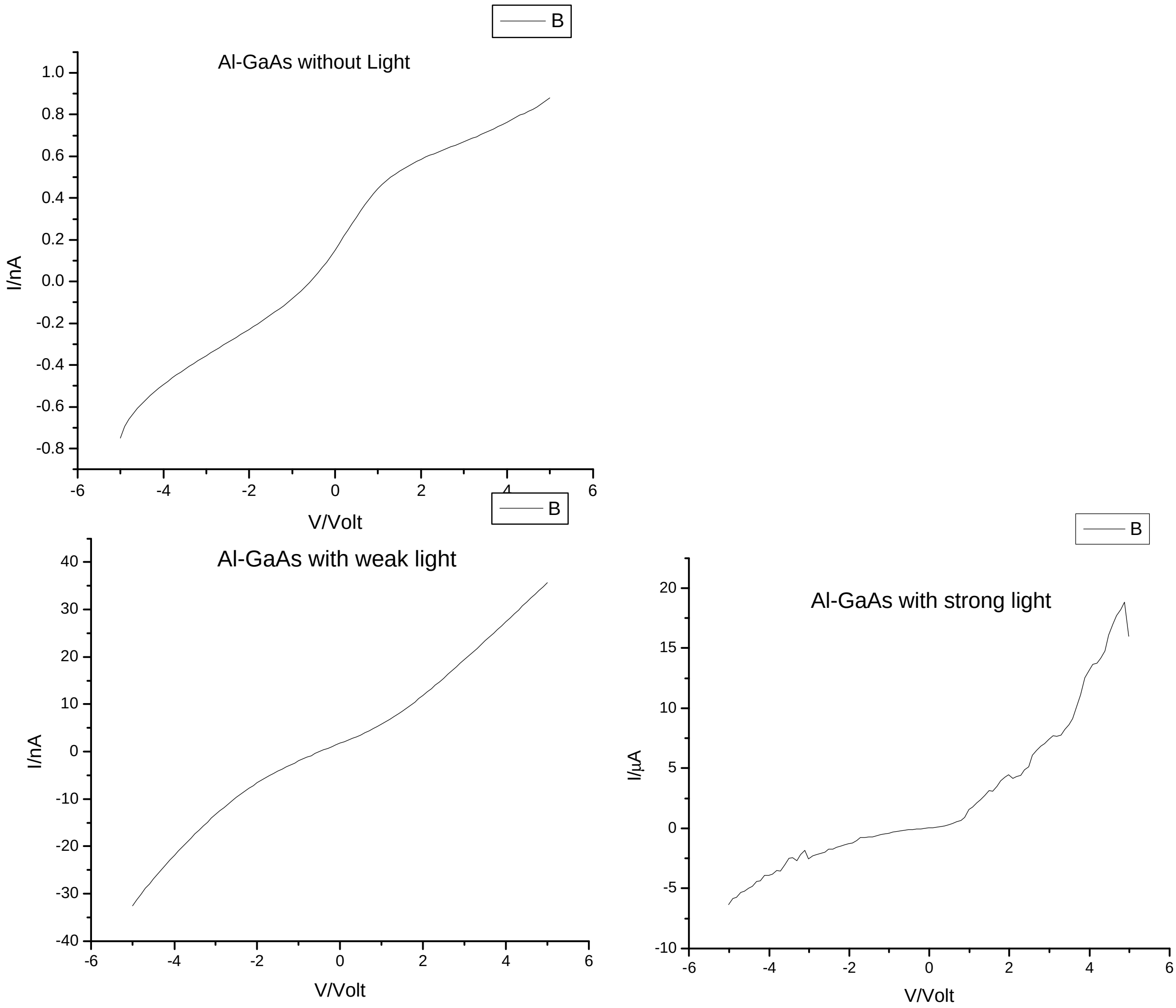




Light Intensity	Result	Voltage range (V)	Current Range (I)	Breakdown Voltage (V)
Strong Light	• **I increase abruptly when V increases beyond the breakdown voltage.**	-5 ~ 5	-2.30788×10^{-4} ~ 1.8926×10^{-3}	~1.5
Weak Light	• **No current in reverse bias.** • **I non-linearly increases when V increases beyond the breakdown voltage.**	-5 ~ 5	1.52658×10^{-7} ~ 3.68587×10^{-5}	~1.2
Without Light	• **No current in reverse bias.** • **I non-linearly increases when V increases beyond the breakdown voltage.**	-5 ~ 5	-4.36018×10^{-8} ~ 2.55174×10^{-5}	~1.2

Table 1 Comparison between different elements when using Silicon substrate with aluminium and gold contacts

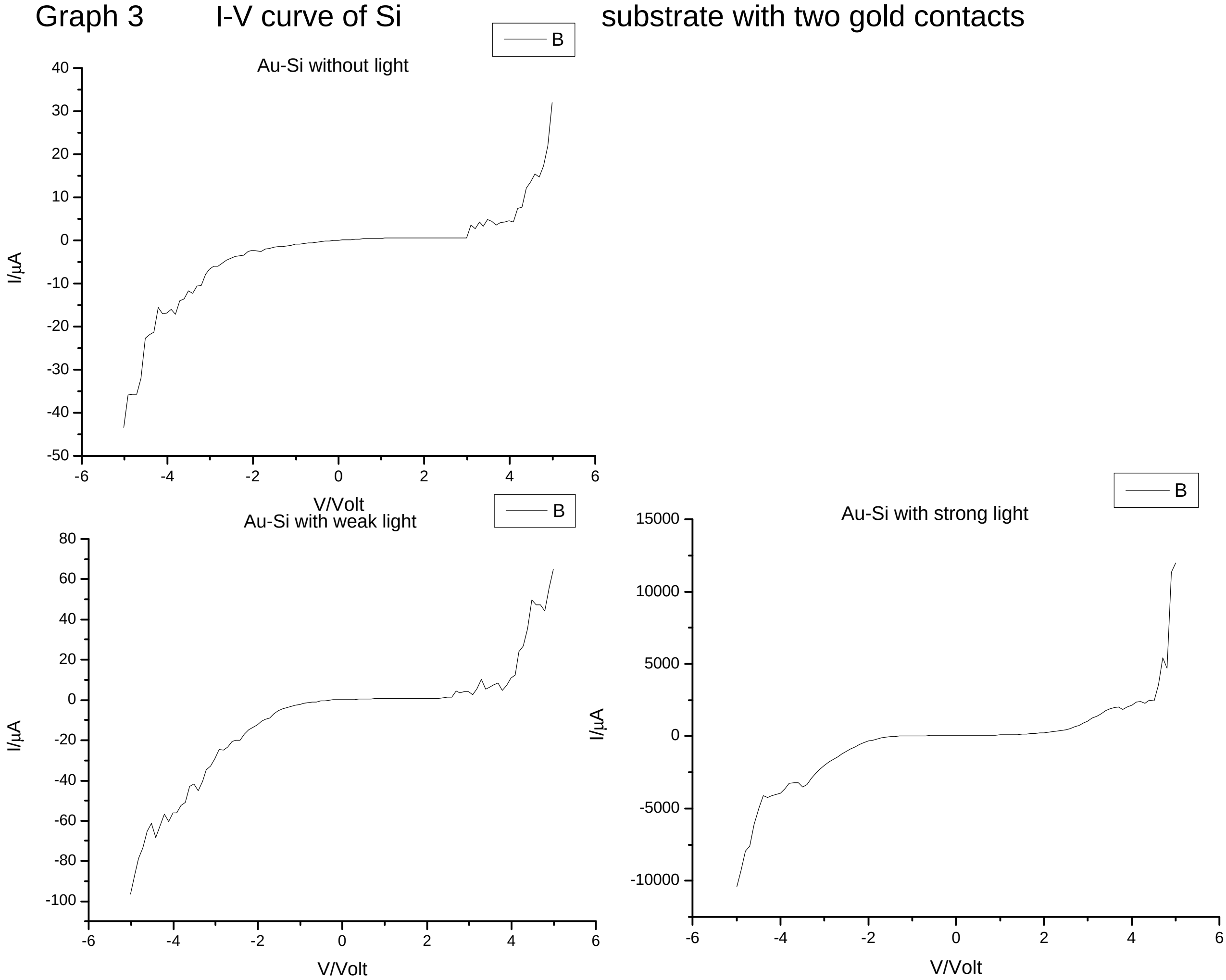
Graph 2 I-V curve of GaAs substrate with aluminium and gold contacts



Light Intensity	Result	Voltage range (V)	Current Range (I)
Strong Light	• **Non-linear.** • **I increases when V increases**	-5 ~ 5	$-6.35582\text{x}10^{-06}$ ~ $1.8808\text{x}10^{-05}$
Weak Light	• **Roughly Directly Proportional**	-5 ~ 5	$-3.26241\text{x}10^{-08}$ ~ $3.56381\text{x}10^{-08}$
Without Light	• **Roughly Directly Proportional**	-5 ~ 5	$-7.4832\text{x}10^{-10}$ ~ $8.7992\text{x}10^{-10}$

Table 2 Comparison between different elements when using GaAs substrate with aluminium and gold contacts

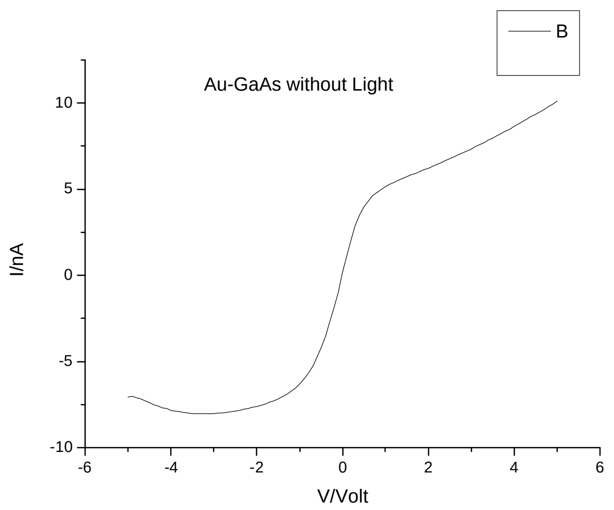
Graph 3 I-V curve of Si substrate with two gold contacts

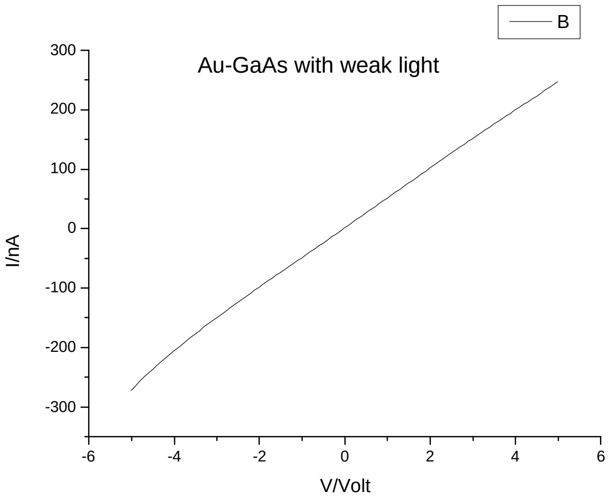


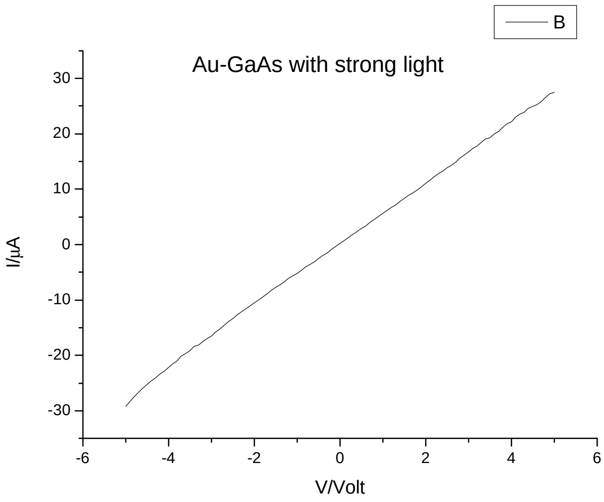
Light Intensity	Result	Voltage range (V)	Current Range (I)	Breakdown Voltage (V)
Strong Light	• **I increases significantly with V beyond the breakdown voltage in the forward bias, and decreases significantly with V beyond the breakdown voltage in the reverse bias** • **Similar to the I-V curve of Zener Diode**	-5 ~ 5	-1.04408×10^{-2} ~ 1.1925×10^{-2}	~ -2(reverse bias) ~ 3(forward bias)
Weak Light	• **I increases significantly with V beyond the breakdown voltage in the forward bias, and decreases significantly with V beyond the breakdown voltage in the reverse bias** • **Similar to the I-V curve of Zener Diode**	-5 ~ 5	-9.67234×10^{-5} ~ 6.4715×10^{-5}	~ -1(reverse bias) ~2.5(forward bias)
Without Light	• **I increases significantly with V beyond the breakdown voltage in the forward bias, and decreases significantly with V beyond the breakdown voltage in the reverse bias** • **Similar to the I-V curve of Zener Diode**	-5 ~ 5	-4.33624×10^{-5} ~ 3.19192×10^{-5}	~ -2(reverse bias) ~ 3(forward bias)

Table 3 Comparison between different elements when using Si substrate with two gold contacts

Graph 4 I-V curve of GaAs substrate with two gold contacts







Light Intensity	Result	Voltage range (V)	Current Range (I)
Strong Light	• **Directly proportional**	-5 ~ 5	-2.9271×10^{-5} ~ 2.73958×10^{-5}
Weak Light	• **Directly proportional**	-5 ~ 5	-2.71929×10^{-7} ~ 2.46891×10^{-7}
Without Light	• **"Snack shape"** • **I increase with V beyond –3V**	-5 ~ 5	-8.03151×10^{-9} ~ 1.01024×10^{-8}

Table 4 Comparison between different elements when using GaAs substrate with two gold contacts

Conclusion

From the result shown by the graph, silicon has a lower sensitivity. This is due to the band gap of silicon (1.11eV) is smaller than that of GaAs (1.43eV). Therefore, GaAs have a higher sensitivity. It is the highest when aluminium and gold are the contacts of the GaAs substrate. On the other hand, an easily measure significant change in the current is obtained when silicon substrate with gold contacts is exposed to different intensity of light.

So the best combination changes according to different situations. If a high sensitivity is needed, GaAs substrate with aluminium and gold contacts is recommended. If the current needed to be easily measure (i.e. large enough and change significantly), silicon substrate with gold contacts is recommended.

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