**MANG3067 Accounting Coursework**

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1. **Choose a technology and explain how it functions.**

Laser diodes are used throughout many industries for a wide range of purposes, ranging from laser pointers to fibre optic internet. There are many different designs for laser diodes, each with its benefits and draw backs. The most basic and fundamental design is a homojunction laser diode.

The basic structure of a diode is two pieces of a semiconductor material placed on top of each other, with each piece of semiconductor having a separate electrical terminal. Silicon (Si) is typically used for regular diodes as it is inexpensive and more readily available than other semiconductor materials. The silicon is grown to form a single crystal, with every atom in the crystal lattice bonded to its neighbours. Silicon is a type IV element, with four free electrons in its outer shell. These four free electrons bond to other silicon atoms in the crystal lattice, leaving no free electrical carriers (electrons or holes). This causes the silicon to act as an insulator, preventing the flow of current. However, if the silicon is doped by adding impurity atoms to the crystal lattice it can be made to conduct. The impurities used are typically type V or type III elements. Type V elements have five electrons in their outer shell. This means that if they are added to the crystal lattice they will add an extra electron which cannot bond to the silicon lattice and flows freely throughout the material. This creates an n-type semiconductor. Type III elements have only three electrons in their outer shell. When they are added to the silicon lattice they can will leave a ‘hole’ where an electron would otherwise be. Holes are also electrical carriers and can be thought of as being comparable to positive electrons. If a semiconductor is doped to have many free holes it is a p-type semiconductor. Impurities are added by firing high velocity atoms at the neutral silicon lattice. These impurities then replace a silicon atom in the lattice.

A semiconductor has two important energy bands which carriers can occupy. These are known as the conduction and valance bands. The conduction band is primarily occupied by free electrons which can flow throughout the device. Similarly, the valance band is occupied by free holes. Carriers in the conduction band have more energy than those in the valance band. This difference in energy levels is know the band gap energy (Eg). The band gap energy is fixed, but varies between different semiconductor materials. When an electron drops from the conduction band to the valance band it annihilates with a hole, and energy equal to the band gap is released, either as heat or light.

A laser diode has a piece of n-type semiconductor placed on top of a piece of p-type semiconductor. These p and n-type semiconductors each have different conduction and valance band energies, but the same band gap energy. N-type semiconductors have a lower energy than p-type.

When no electric field is applied to the device this difference in energy levels prevents the flow of carriers. However, if the device has a forward bias electric field applied to it the barrier to conduction is decreased and electrons from the n-type semiconductor are able to flow into the p-type, and quickly annihilate with holes.

During the operation of a laser diode an electron drops from the conduction band to the valance band, annihilating with a hole and releasing it’s energy (Eg) as a photon. The device has mirrors on either end to prevent this photon from escaping. The photon then causes another electron to drop from the conduction band to the valance band, releasing another photo. This causes a chain reaction, and soon the laser cavity is filled with laser light. Some of this laser light is allowed to escape the device via a small hole in the mirror. This laser light is unfocused, and must be passed through a collimating lens in order to focus it into a beam. This is where the name laser originates from as it is an acronym for ‘light amplification by stimulated emission of radiation’.

The wavelength (and therefore colour) of the laser light is defined by Eg­ with higher values causing a lower wavelength. The designer of the device chooses a semiconductor material so that it has a desired ­Eg, causing emission of a desired wavelength of light.

Silicon is not an ideal semiconductor for the creation of laser diodes as it is an indirect semiconductor. This means that in order for electrons to drop from the conduction band to the valance band heat must be released prior to a photon. This has the effect of making stimulated emission much more unlikely. Indium Gallium Arsenide (InGaAs) is a direct compound semiconductor, making stimulated emission of photons much more likely. The doping of the InGaAs can be varied by changing the amount of each element that goes into the compound, as In and Ga are type III elements and both have free holes, whereas As is a type V element and has free electrons.

Homojunction laser diodes are very inefficient, but there are many laser diode designs with better efficiency. One once such design is a double heterojunction laser diode. This design has five separate semiconductor layers, rather than two, and is therefore more expensive to fabricate.

1. Provide a non-financial engineering measure of performance that describes your product/process.

The homojunction laser diode modules are produced in a fabrication plant, ran by a large number of staff. The company supplies laser diode modules to manufacturers to be used in their products.

Inputs:

Raw materials

* Si wafers, InGaAs, Cu, Au  **variable**

Resources

* Electricity, water, **variable** Food (canteen), Office supplies, Gas (heating) **fixed**

Other

* Facility insurance **fixed**

Outputs:

* Laser diode modules

1. Explore what costs would be incurred by changing the technical parameter.

The technical parameter to be varied is the efficiency of the laser diode. This is done by changing the design from a homojunction, to double heterojunction laser diode.

The cost of materials would remain largely unchanged as both designs use the same amount of doped InGaAs as a semiconductor.

A new fabrication plant would not have to be constructed as the fabrication method remains largely unchanged. However, new equipment will need to be purchased for the current fabrication plant. As the fabrication plant is switching over to a new design, engineering staff will have to be retained to use the new equipment

Approximate staffing requirements:

200 Engineers, 400 other staff (cleaners, canteen workers, delivery drivers), 100 administrative workers (managers, accountants, advertisers)

Costs:

Production cost

Direct costs

Direct Materials – more electricity

Direct Labour – more staff

Direct Expenses

Indirect costs

Production Overheads

Selling & Distribution Overheads

Administration Overhead

Selling cost

Administration cost

* Retraining staff
* Hiring new administrative team and staff
* Advertising campaign to promote new product
* Cost of materials