ABSTRACT

An investigation on the electrical properties of nanocrystalline silicon (nc-Si) thin film prepared by 150MHz VHF PECVD has been done. Silane and Argon was used as reactant gases. Two devices (labeled Devices 1 and Device 2) with different nc-Si thin film were prepared. For each devices deposition parameters were, substrates temperature is 300K, reactant gas flow rate is 5 Sccm, growth pressure is 4.5 x 10^{-2} and frequency power is 11 watt. Meanwhile, deposition time for Devices 1 is 600 s and Devices 2 is 1800 s. Thicknesses of film was determined by using ellipsometer. We obtain nc-Si thickness for the Device 1 is 48 nm and for Device 2 is 70 nm. Sandwich of nc-Si with aluminum electrode (Al/nc-Si/Al) was tested in cryostat to determine devices I-V characteristics at different thickness and temperature. The I-V characteristics of Al/nc-Si/Al with different nc-Si thickness clearly showed the variation of conduction mechanisms from ohmic to trap limited space charge limited current (SCLC). It is suggested that the trap were indicated present of nanocrystalline structure in amorphous crust. Through calculation, the trap density, N_t for Device 1 is 3.194 x 10^{30} m^{-3} and 8.055 x 10^{30} m^{-3} for Device 2. The trap density for both measurements was found to be decrease as the nc-Si thickness increase and for transition voltage it is vice versa. It is observed that SCLC conduction mechanism also influence at low temperature, where as the temperature increase the trap density were increase and transition voltage were decrease. From SCLC conduction mechanism parameters, we obtain that the activation energy of traps for Device 1 is 0.44 eV and for Devices 2 is 0.39 eV.

ABSTRAK

Satu kajian bekenaan sifat elektrik terhadap saput tipis nanokristal silikon (nc-Si) yang disediakan menggunakan 150MHz VHF PECVD telah dijalankan. Gas Silane dan Argon digunakan sebagai gas tindakbalas. Dua saput tipis (dilabel Alat 1 dan Alat 2) yang mana masing-masing mempunyai ketebalan 70 nm dan 48 nm telah disediakan. Untuk setiap alat parameter pemendapan saput tipis nc-Si adalah, suhu substrat ditetapkan pada 300K, kadar pengaliran gas tindakbalas adalah 5 Sccm dan tekanan adalah 4.5 x 10-2 torr. Sementara, masa pemedapan untuk Alat 1 adalah 600 s dan Alat 2 adalah 1800 s. Ellipsometer telah digunakan untuk pengukuran ketebalan saput tipis. Kita mendapati ketebalan saput tipis nc-Si untuk Alat 1 adalah 48 nm dan Alat 2 adalah 70 nm. Saput tipis nc-Si ditindih diantara dua elektrod aluminium (Al/nc-Si/Al) untuk penetuaan ciri I-V menggunakan cryostat pada suhu berlainan. Didapati ciri I-V bagi Al/nc-Si/Al pada ketebalan nc-Si yang berlainan menunjukkan perubahan mekanisme pengaliran dari ohmic ke ruang cas yang telah menghadkan pengaliran arus. Hasil ini memberi cadangan akan kehadiran struktur nano Kristal didalam struktur amorphos yang bertindak sebagai perangkap. Menerusi pengiraan, ketumpatan perangkap, N_t untuk Alat 1 adalah 3.194 x 10^{30} m^{-3} dan 8.055 x 10^{30} m^{-3} untuk Alat 2. Didapati ketumpatan perangkap berkurangan apabila ketebalan nc-Si bertambah dan sebaliknya bagi voltan peralihan. Didapati juga mekanisme pengaliran ruang cas yang telah menghadkan pengaliran arus juga mempengaruhi pada suhu rendah, dimana apabila suhu bertambah ketumpatan perangkap bertambah dan voltan peralihan berkurangan. Daripada parameter mekanisme pengaliran pengaliran ruang cas yang telah menghadkan pengaliran arus, didapati tenaga pengaktifan perangkap untuk Alat 1 adalah 0.44 eV dan untuk Alat 2 adalah 0.39 eV.

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CHAPTER 1

INTRODUCTION

The most successful breakthrough in vacuum physics is deposition of thin film. Thin film or also called nanofilm is general term for a layer of material deposited on a substrate at thickness less than 1000 nm. For a layer of thin film, the characterization can be made base on properties such as topography, internal properties, composition, optical properties, electrical properties, magnetic properties, mechanical properties and chemical properties. Thin film materials can be metal, semiconductor and insulator. These material is categorized by their electrical resistivity or conductivity as follow $10^{-8} < \rho_{metal} < 10^{-4}\Omega cm < \rho_{semiconductor} < 10^{4}\ \Omega cm < \rho_{insulator} < 10^{10}\ \Omega cm$ or higher.

In recent years, the application of thin film is synonyms as optical coating. It is usually used as anti reflection coating and it works by interference of two reflected light at thin film interface. Recently it is scientifically proven to be used as semiconductor, where thin films semiconductor is used as the building block for thin film transistor

(TFT) and single electron transistor (SET) in electronic device. Plus it also can be found in solar cells. These are possible, due to unique characteristics of Nanocrystalline silicon (nc-Si) thin film. Compatibility of nc-Si as transistor and solar cell prove it poses a good electrical conductivity. Conductivity of bulk material is different compare to nano size material. Thus there are different in I-V characteristics and carrier transport mechanism of bulk and nano size material.

In this study nc-Si will be prepared in thin film form with different thickness and from it I-V characteristics the carrier transport mechanism can be determine. Thus, base on a glance of information above it is very important to study the electron transport phenomenon in these films to enable materials to be tailored for diverse device applications.

1.1 Background of the study

For the past few decades silicon has been know as a material that can conduct electricity in the magnitude range of conductor and insulator. Current flow are cause by transport of electrons and holes in the crystalline structure of material. Pure silicon was first produced in 1823 by Jöns Jakob Berzelius from it work on electrolyze of molten mixture of pottasium metal and potassium silicon fluride. Jöns Jakob Berzelius named it first as silicium and later in 1831 it is named as silicon by Thomas Thomson due to it characteristic. Continues research on this material have brought major impact in electronic and optoelectronic application. Recent breakthrough reported that silicon has become the material of interest in photonic industries, where its use in making transiver, cell processor and biosensor.

Today there are different types of silicon which depend on it growth technique. The most promising application in feature is nanocrystalline silicon (nc-Si). The nanocrystalline is referring to the size of it crystalline. Deposition of nanocrystalline silicon thin film was first reported in 1967, where silicon was sputtered and the product was transferred to substrate in low temperature condition (Veprek and Maracek, 1967). Currently nc-Si are the most potential material in solar cell thin film manufacture, this is due to it high efficiency conversion of light into electrical energy and low cost production. The increase in efficiency is due production of multiple electrons due to absorption of high energy blue and ultraviolet light (Nozik, 2007). In typical solar cell, blue and ultraviolet light is converting into heat.

Work by Tan *et al* (2003), demonstrated that a single electron transistor (SET) can be fabricate using nc-Si. The basic structure of SET consist of 20 nm thick nc-Si and 150 nm silicon dioxide which grown on n-type crystalline silicon. By altering grain boundaries of nc-Si through oxidation and annealing process this SET can be operate at room temperature. The structure of room temperature nc-Si SET is illustrated in Figure 1.1. Since nc-Si is potential to be used as electronic device, thus it is obligation to study it conduction mechanism. For thin film there are few conduction mechanism which can be extract from it I – V characteristics, such as space charge limiting current (SCLC), Scottky emission, Fowler-Nordehaim tunelling and Pooled-Frackel effect.

Growth technique for nanocrystalline silicon thin film has undergo transformation since it was discover in 1968. The growth or generally term as deposition is divided into two process which is physical vapour deposition (PVD) and chemical vapour deposition (CVD. There is great variety of reactor types for CVD, such as plasma enhanced chemical vapour deposition (PECVD), metal-organic chemical vapour deposition (MOCVD) and hot wire chemical vapour deposition (HWCVD). Thin film deposited using PECVD has properties of good adhesion, low pin hole density, and excellent uniformity.

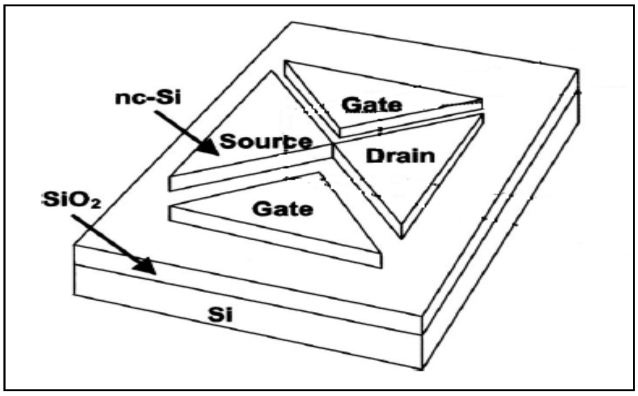

Figure 1.1: Schematic diagram of SEM. Nanocrystalline silicon deposited thick silicon dioxide layer grown thermally on an *n*-type crystalline silicon substrate (Tan *et al.* 2003).

So far there are few publish paper related to this research that focus on this material compare to hydrogenate nanocrystalline silicon and hydrogenate amorphous silicon. For this reason, it is worthwhile to carry out researches to drill a better and profound understanding to the conduction mechanism of nanocrystalline silicon thin film and thus enhancement of device that base of nanocrystalline silicon can be made.

1.2 Statement of problem

Nanocrystalline silicon (nc-Si) has interesting features due to its unique structure that can be manipulated for nanodevice applications. The current– voltage (I-V) characteristics of nc–Si is somewhat misunderstood because the curve patterns may vary with the experimental conditions. Thus this experiment will attempt to investigate nc-Si thin film I – V characteristics curve pattern and to obtain it conduction mechanism at various temperature.

1.3 Objective of the study

1 To fabricate samples with Al/nc-Si/Al structures using the conventional evaporation technique (eletrodes) and 150MHz VHF PECVD (nc-Si).

2. To measure and analyze the current – voltage characteristics of Al/ ncSi /Al structure at different temperature and nc-Si thin film thickness..

3. To identify the nature of conduction mechanism.

1.4 Scope of study

In this research, we deposit three layer of thin film by using evaporator for aluminum electrode and PECVD for nc-Si on corning glass. The deposition time for each nc-Si thin films are different,so we can obtain nc-Si thin film at different thickness.. The dimensions of each thin films layer were depending on custom made aluminium mask. Then, I-V characteristics of our samples were determined by using I-V measurement system with cryostat at low temperature. Finally, the resulting plots will be used to account for the possible conduction mechanism occurring in nc-Si thin film.

1.5 Significant of the study

This research will guide us making further understanding on conduction mechanism of nanocrystalline silicon where it application is important in optoelectronic and electronic samples. We also can distinguish and understand the operation of two deposition technique use in this research, where thermal evaporator is classified as physical process and PECVD as chemical process.