CRYSTALLIZATION OF POLYCRYSTALLINE SILICON THIN FILM BY EXCIMER LASER ANNEALING

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Specially dedicated to my beloved mom, Pn. Halimah Kaliwon,
dad, Ab. Razak Sarkawi,
brothers, Rahim and Fahmi,
sisters, Nora, Dayah, Ayu, and Zura,
and all my friends..
Thank you for your love and support.
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ABSTRACT

Enhancing the crystallization of silicon thin film is important for better performance of thin film transistor (TFT). In an attempt to achieve this goal,a fundamental study was carried out to enhance the crystallization of doped silicon thin film (STF) with various types of dopants. The dopants used in this research are copper, aluminium and germanium. Initially the amorphous silicon (a-Si) film was prepared by low pressure physical vapour deposition (PVD). The STF was annealed using a combination of two techniques. Firstly, the doped STF was annealed by conventional method using tube furnace. Secondly, annealing was done using argon fluoride (ArF) excimer laser. The microstructure of thin film was analyzed using metallurgical technique via field emission scanning electron microscope(FESEM) and atomic force microscope (AFM). In general the grain size of doped STF increased with the energy density of the excimer laser except for Si:Ge. However, the crystallization was found to decrease after exceeding the critical or super lateral growth (SLG) energy. The optimum grain size achieved by Si:Cu, Si:Al, and Si:Ge thin film were 143.2, 129.2 and 105.6 nm respectively at the corresponding SLG energy each of 345.00, 356.11, and 413.78 mJcm^{-2} respectively. Copper was found to be the best dopantbased on its largest grain size achievement. The enhancement of crystallization was also carried out using single heat treatment that are a conventional furnace heat treatment and directly using ELA separately. Apparently, the combination of the two techniquesoffers better performance in comparison to any single heat treatment.

ABSTRAK

Peningkatan penghabluran saput tipis silicon adalah sangat penting untuk mendapatkan prestasi transistor saput tipis (TFT) yang lebih baik. Dalam usaha untuk mencapai matlamat ini, kajian asas telah dilaksanakan bagi membesarkan struktur Kristal saput tipis silikon (STF) dengan pelbagai jenis dopan. Dopan yang digunakan dalam kajian ini ialah kuprum, aluminium, dan germanium. Sebagai permulaan, saput tipis silicon amorfos disediakan melalui pemendapan wap bertekanan rendah (PVD). Saput tipis STF disepuhlindap dengan menggunakan kombinasi antara dua teknik. Pertama, STF berdop disepuhlindapkan melalui kaedah konvensional menggunakan tiub relau. Kedua, sepuhlindap dilaksanakan menggunakan laser eksimer argon florida (ArF). Mikrostruktur saput tipis dianalisa menggunakan teknik kaji logam melalui mikroskop imbasan kesan medan electron (FESEM) dan mikroskop daya atom (AFM). Secara umumnya, saiz butiran STF berdop bertambah dengan ketumpatan tenaga laser eksimer kecuali bagi Si:Ge. Walaubagaimanapun, pertumbuhan didapati berkurangan selepas melebihi takat genting atau tenaga super pertumbuhan sisi (SLG). Saiz butiran optimum yang dicapai untuk saput tipis Si:Cu, Si:Al, dan Si:Ge masing-masing adalah 143.2, 129.2 dan 105.6 nm yang berpadanan dengan tenaga SLG iaitu 345.00, 356.11, dan 413.78 mJcm^{-2}. Kuprum telah didapati sebagai bahan dop yang terbaik berdasarkan pencapaian saiz butiran yang terbesar. Peningkatan penghabluran juga dilaksanakan melalui proses pemanasan tunggal secara berasingan dengan menggunakan kaedah konvensional dan ELA secara terus. Jelas menunjukkan bahawa kombinasi antara dua teknik menawarkan peningkatan yang lebih baik berbanding dengan rawatan pemanasan tunggal.

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LIST OF SYMBOLS

A - Absorption
Al - Aluminium
Ar - Argon
c - Speed of light
Cl - Cluorine
Cu - Copper
d - thickness of thin film
E - Photon energy
eV - Electron Volt
F - Force
Fl - Fluorine
g - gram
Ge - Germanium
h - Planck’s constant
I - Intensity of light
k - stiffness of a lever
Kr - Kripton
kV - kilo volts
mm - milimeter
Nm - nanometer
ns - nanosecond
Si - Silicon
Si_3N_4 - Silicon nitride
T - Light transmition
v - Electromagnetic wave

Xe	-	Xenon
z	-	the distance the lever is bent
α	-	Absorption coefficient
β	-	A constant value
λ	-	Wavelength of the light
μA	-	micro Ampere

ABBREVIATIONS

AFM	-	Atomic force microscope
AMLCD's	-	Active matrix liquid crystal displays
ArF	-	Argon fluoride
a-Si	-	Amorphous silicon
CVD	-	Chemical vapour deposition Deposition
ELA	-	Excimer laser annealing
ELC	-	Excimer laser crystallization
FES	-	Field emission source
FESEM	-	Field effect scanning electron microscope
LTPS	-	Low temperature poly-silicon
PEVCD	-	Plasma-Enhanced Chemical Vapor-
Poly-Si	-	Polycrystalline silicon
P_V		Vacuum pressure
PVD	-	Physical vapour deposition
SEM	-	Scanning electron microscope
SLG	-	Super lateral growth
SPC	-	Solid phase crystallization
SPM	-	Scanning probe microscope
STF	-	Silicon thin film
TFTs	-	Thin film transistors
UV	-	Ultraviolet
UV-Vis	-	Ultraviolet-Visible

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CHAPTER 1

INTRODUCTION

1.1 Overview

Thin film transistors (TFTs) are well known devices utilizing thin film semiconductor. The TFTs are fabricated by forming a thin film semiconductor on a substrate and processing the thin film semiconductor (Ohtani, *et al.*, 2003). The TFTs are used in various types of integrated circuits, and are particularly in electro-optical devices, liquid crystal display devices and flat panel displays such as camera viewfinders, car navigation systems, laptops, televisions and etc. Due to their large field effect mobility and high current driving capability (Park, *et al.*, 1999), polycrystalline silicon (poly-Si) TFTs has been extensively investigated for the application in active matrix liquid crystal displays (AMLCDs).

There are various methods available to fabricate poly-Si thin film, either direct or indirect deposition method. However, direct deposition has the problem of rough topography, which is due to high-density of atomic hydrogen in the gas phase caused several etching of the silicon surface (Yogoro, *et al.*, 2003). Re-crystallization of amorphous silicon (a-Si) using excimer laser annealing (ELA) is known as the best method to fabricate a good poly-Si because it can heat the film up to the melting point and at the same time no thermal damage occur into the glass substrate (Carluccio, *et al*., 1997; Matsumura, *et al*., 1999).

ELA technique is widely used to increase the grain size (Gall, *et al.,* 2002) and the microstructure of poly-Si thin film which is the most important characteristics of excellent built-in poly-Si devices (Marmostein, *et al.,* 1999; Palani, *et al*., 2008). The advantage of using excimer laser is the strong absorption of ultraviolet (UV) light in silicon.

1.2 Significance of The Study

Early research of silicon thin film fabrication required high temperature corning glass substrate due to high annealing temperature, which is higher than 650°C and longer period of annealing process, that is over 10 hours. By using two step annealing techniques, an inexpensive glass substrate can be used, compared with expensive quartz substrate. In this present research, a microscope glass substrate is used, which can be heated up to 350°C. At the same time, the annealing temperature can be reduced. In addition, the short pulse duration of excimer laser would shorten the time duration of laser annealing. By reducing the annealing time and temperature, the fabrication cost become much cheaper, faster and clean technique.

1.3 Objective of The Study

The main objective of this project is to enhance the crystallization of poly-Si thin film by using ELA technique. This is achieved by performing the following works;

1. To determine the appropriate laser parameters for annealing,
2. To optimize the doping of catalyst agent, and
3. To characterize the laser annealing of polycrystalline silicon.

1.4 Research Scope

This research focuses on enhancing the crystallization process that specifies the material used as specimen, the equipment employed in conducting the experiment and technique for analysis. Basically, glass slide was utilized as a substrate. A few numbers of catalysts were selected to dope on the silicon base including aluminium, germanium and copper. The thin film was prepared by using thermal vapour deposition. The amorphous silicon (a-Si) was initially heated using a conventional furnace to hydrogenate. Argon fluoride, (ArF) excimer laser was used as a source of annealing. The annealing materials were later characterized by metallurgical methods using field emission scanning electron microscope (FESEM) and atomic force microscope (AFM).

1.5 Thesis Outline

This thesis is devided into six main chapters. Chapter 1 briefly explained the research project which consists of an introduction of TFTs devices which is widely used in our daily life. The objectives and the scope of the study are also discussed in this chapter.

Some similar researches done by previous researchers were reviewed in Chapter 2. Several circumstances and the outcome results were highlighted. Some of those were selected to be as guideline in this work.

The theory of excimer laser annealing, physical vapour deposition, crystalline silicon, photon energy and the optical properties of thin film are discussed in Chapter 3.

The research methodology and experimental procedure are described in details in Chapter 4. The discussions also cover details the apparatus, material and machines that were used in experimental work.

The data obtained from this experiment consists of the microstructure due t crystallization. The observed results were used to measure the grain size and analyzed the relationship with respect to the number of pulse. The details of this results are explained in Chapter 5.

The final chapter summarizes the whole work and addresses the problems experienced throughout the experiment. For further study in this area, along with some suggestions are given in this chapter.

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