RE-CRYSTALLIZATION OF METALLIZED SILICON WAFER WITH COPPER FILM BY Q-SWITCHED Nd:YAG LASER

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This thesis is dedicated to

my beloved

*mom (*Fatima Sadiq*), dad (*Millad Ahmed Alegaily*),*

my bro (Ahmed , Abu Bakr , Ejaily , Mahmoud ,Salah and Mohamed.)

my sis (Halima, Najah, Fahima and Saeda)

and all my friends.

Thank you for being with me all along.

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ABSTRACT

The polycrystalline thin copper films on semiconductor substrates are of interest for many semiconductor devices. Hence the aim of this research is to re-crystallize copper silicon thin film. In order to achieve this objective, the Q-switched Nd:YAG laser was employed as a source to re-crystallize the doped silicon thin film (STF) with copper. A silicon thin film was prepared via low pressure physical vapor deposition (PVD). The STF was annealed by two techniques, first by using conventional method via tube furnace, second by using Q-switched Nd:YAG laser annealing. The microstructure of thin film was analyzed using Atomic Force Microscope (AFM). The results showed that, the grain size of the copper film increased with the energy density of the Nd:YAG laser. However, the grain size was found to reduce after exceeding the critical energy. The large grain size obtained for copper silicon thin film was 2426.04 nm at the corresponding energy density of 3989.48 mJ/cm^{-2}.

ABSTRAK

Filem tipis kuperam polikristalin di atas substrat semiconductor adalah sangat diminati untuk kebanyakan alat semikonduktor. Oleh itu matlamat kajian ini adalah untuk kristalasasi semula filem tipis kuperam. Untuk mencapai objektif ini , Q-suiz Nd:YAG laser di gunakan sebagai sumber untuk kristalasasi semula bagi kuperam filem tipis. Filem tipis kuperam disediakan di bawah tekanan rendah endapan wap Fizik (PVD). Filem tipis di separuh lindap melalui dua teknik. Pertama menggunakan kaedah konvensional melalui tiub ketuhar. Kedua menggunakan separuh lindap Q-suiz Nd:YAG laser. Mikrostruktur filem tipis di analisis menggunakan Mikroskop daya atom (AFM). Keputusan yang perolehi menunjukkan, saiz butiran filem kuperam bertambah dengan ketumpatan tenaga Nd:YAG laser. Walaubagaimanapun proses pengkristalan mengurang setelah melepasi tenaga kritikal. Saiz butiran optimum yang diperolehi untuk kuperam filem tipis adalah 2426 nm perpadanan pada ketumpatan tenaga 3989.48 $mJcm^{-2}$.

TABLE OF CONTAINTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

A^0	-	Angstrom
cm	-	Centimetre
Cu	-	Copper
F	-	Force
K	-	the stiffness of the lever
nm	-	Nanometer
ns	-	Nanosecond
Si	-	Silicon
Z	-	the distance of lever
µm	-	Micrometer

ABBREVIATION

AFM	-	Atomic force microscope
a-Si	-	Amorphous silicon
CW	-	Continuous wave
Poly-Si	-	Polycrystalline silicon
P_v	-	Vacuum pressure
PVD	-	Physical vapour deposition

CHAPTER I

INTRODUCTION

1.1 Introduction

Metal-semiconductor contacts are common components in semiconductor device. Such contacts cannot be assumed to have a resistance as low as that of two connected metals. A proper choice of materials can provide a low resistance. Deposition of a continuous metal coating on a semiconductor substrate has considerable interest in microelectronics for the production of integrated devices. In this context, metallization of silicon surfaces is a stringent issue in the ultra large-scale integrated (ULSI) circuit fabrication industry. It is of importance due to the decrease of device feature sizes (Eftekhar, 2003). Metallization plays a key role in the production process of integrated devices. Metallization is the process that connects individual devices together by means of microscopic wires to form circuits. Thin copper films on semiconductor substrate are of actual interest for the metallization in microelectronic device. Recently, considerable attention has been paid to copper as an alternative material to aluminum. The electrical and structural properties of thin copper films attract increasing attention nowadays because of the use for on-chip interconnections. The main advantages of copper are the excellent conductivity and the relatively high stability against electro migration damaging (Bru¨ggemann, *et al*., 2002). Due to their large field effect mobility and high current driving capability, polycrystalline (poly-Si) of copper thin film has been extensively investigated for the applicant in microelectronics for the production of integrated devices (Yogoro, *et al*., 2003).

There are many methods available for metallization of Si surfaces, Physical Vapor Deposition (PVD) is one of the promising methods to fabricate poly-Si thin film. However, this method has problem of rough topography. This is due to high-density of atomic hydrogen in the gas phase causes the etching of silicon surface (Yogoro, *et al*., 2003). General means for obtaining a polysilicon film is a technique in which an amorphous silicon film is crystallized into a polysilicon film. A method in which an amorphous silicon film is crystallized with the use of laser light has lately become the one that is especially notable. In this specification, to crystallize an amorphous semiconductor film with laser light to obtain a crystalline semiconductor film is called laser crystallization.

Laser annealing is advantageous to produce the high quality poly-Si films with large grains and low dislocation density controlled by the pulse duration and optical absorption depth of the laser light in Si films (Jin *et. al*, 2010).

Laser can be considered as an excellent tool in microelectronics technologies. Its radiation can be brought to a desirable place, exposure is precise, the beam is stable and homogeneous. A low divergency of the beam gives a possibility to focus the radiation onto small spots: there is a possibility of direct "drawing". The ability to change the wavelength is also a great advantage: specific substances can be processed. These factors provide completely new technological capabilities (Mikhailova *et. al*., 1993).

1.2 Background

Metallization refers to the metal layers that electrically interconnect the various device structures fabricated on the silicon substrate. Thin copper films on semiconductor substrate are of actual interest for the metallization in microelectronic device (Bru¨ggemann, *et al*., 2002). There are many methods available for metallization of Si surfaces, Physical Vapor Deposition (PVD) is one of the promising methods to fabricate poly-Si thin film. However, this method has problem of rough topography, which is due to high-density of atomic hydrogen in the gas phase caused several etching of silicon surface (Yogoro, *et al*., 2003). The electric characteristics of the amorphous copper silicon film are disadvantageously poor. Electron has the lowest mobility in amorphous Cu-Si film which has neither short nor long range atomic order. The use of a thin film of crystalline Cu-Si thin film can solve the problem.

Most metal-semiconductor contacts are annealed after the initial deposition of the metal in an effort to further improve the contact resistivity (Bart, 2011). Crystallization is the process of formation one or more materials from solution, melt or gas phase into a crystalline state. Re-crystallization by solid state laser annealing is an efficient technology for obtaining high-performance polycrystalline Si thin -film. Further, both the front side and the back side of an amorphous semiconductor thin film is irradiated with such laser light to obtain the crystalline semiconductor thin film with a larger crystal grain size, which mean low contact resistivity (Yamazaki, *et al*., 2004).

1.3 Problem statement

Conventional annealing normally expensive and desires long period to process. This is because the process involves the application of high quality substrate like quartz or BK7 to stand with high temperature environment and long period of heat treatment in the furnace. An alternative way is needed to solve this problem. Laser annealing has offered a superior technique because of its low fabrication cost and high efficiency.

The annealing process can be performed in short time. It is a low temperature processing technique because during the fast heating and cooling cycle the bulk substrate material is essentially unaffected. Pulsed laser annealing technique is proposed to increase the grain size and controlling the microstructure of poly-Si thin film.

This study intends to propose a new technique for re-crystallize of metalized silicon thin film by using Nd:YAG laser at different energy.

1.4 Research Objectives

The objective of this project is to metalize silicon wafer by using combination technique through heat treatment and Nd:YAG laser annealing. In attempt to achieve this goal, the work details are as follows:

1. To metalize silicon wafer by copper thin film
2. To anneal by conventional method through heat treatment

3. To anneal by Nd:YAG at different energy
4. To analyze the metalized copper film via AFM

1.5 Research Scope

In this project the investigation will focus on deposit copper thin film on silicon wafer. The silicon copper thin film will be fabricated using pressure vapor deposition. The silicon copper thin film is heat treated via tube furnace. The dehydrogenated amorphous silicon copper thin film is recrystallized via Nd:YAG laser annealing. The crystallization is quantified based on grain size measurement. Atomic force microscope is utilized for analysis.

1.6 Significance of the Study

Laser re-crystallization has been demonstrated as an efficient technology for obtaining polycrystalline silicon (poly-Si) thin film. In order to improve grain size, uniformity and hence device performance, the laser recrystallization technique was developed. Hence, this research was carried out in order to produce one of the ideas to perform the Laser recrystallization by using a Nd:YAG laser annealing.

1.7 Chapter Outline

This project proposal is divided into five main chapters. The first chapter has attempted to overview the project including the significance, the objectives and the scope of the study. The aim for this chapter two is to discuss some similar research done by reviewing previous work. It will then move to discuss the basics and theory of Nd:YAG laser annealing and physical vapor deposition. Chapter three describes the research methodology and experimental procedure which cover the apparatus, material and machine employed in this experiment. In chapter four the results from the experiment will be analyzed and discussed. The relationship and the comparison will be made upon the results. Finally the conclusion of the project is described in chapter five. This includes the summary of the whole project. Some works to be carried out in the future are suggested.

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