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ScienceDirect
Thin Solid Films 515 (2007) 6615–6618
www.elsevier.com/locate/tsf

Electrical properties of ultra-thin oxynitrided layer using N_2O plasma in inductively coupled plasma chemical vapor deposition for non-volatile memory on glass

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Available online 11 January 2007

Abstract

In this work, the silicon oxynitride layer was studied as a tunneling layer for non-volatile memory application by fabricating low temperature polysilicon thin film transistors on glass. Silicon wafers were oxynitrided by only nitrous oxide plasma under different radio frequency powers and plasma treatment times. Plasma oxynitridation was performed in RF plasma using inductively coupled plasma chemical vapor deposition. The X-ray energy dispersive spectroscopy was employed to analyze the atomic concentration ratio of nitrogen/oxygen in oxynitride layer. The oxynitrided layer formed under radio frequency power of 150 W and substrate temperature of 623 K was found to contain the atomic concentration ratio of nitrogen/oxygen as high as 1.57. The advantage of high nitrogen concentration in silicon oxide layer formed by using nitrous oxide plasma was investigated by capacitance–voltage measurement. The analysis of capacitance–voltage characteristics demonstrated that the ultra-thin oxynitride layers of 2 nm thickness formed by only nitrous oxide plasma have good properties as tunneling layer for non-volatile memory device.

Keywords: Tunnel oxynitride; Nitrous oxide (N_2O); Plasma-assisted oxynitridation; Non-Volatile Memory (NVM)

1. Introduction

Low temperature polysilicon (LTPS) on the glass has been widely investigated as a material for applications such as flat panel display and organic light emitting diodes (OLED) because the electron mobility of low temperature polysilicon (poly-Si) thin film transistors (LTPS-TFT) is about 100 times larger than that of the conventional amorphous silicon TFT. Many new functional devices on the glass have been fabricated and studied recently for circuit integration, brightness improvement, and device stability. Many methods have been used in OLED in order to improve flawed device, yet the performance of the OLED is not satisfactory in brightness and efficiency. When the display shows a static image, the power consumption increases, the brightness of panel degrades with time, and driving current also changes. To solve the problems about the increase of power consumption, degradation of brightness and change of driving current, dynamic memory is applied to polysilicon on the glass [1,2]. Though the dynamic memories are sufficiently worked out, suitable solutions to problems such as power consumption and the brightness of panel still remain to found. The non-volatile memory (NVM) device on glass is generally used for image storage in the electric devices and can be applied to reduce degradation in brightness of the panel. The LTPS NVM can be used to control brightness using the function of non-volatile and image storage of next generation electric products such as portable terminals.

However, there are still several issues such as high manufacturing cost, nonuniformity over a large area, high surface roughness, and degradation in TFT performance under bias stress to be addressed. Among the various techniques to achieve large area poly-Si on glass, excimer laser annealing (ELA) is the most frequently used technique because of the high quality poly-Si and low temperature process using a buffered layer on glass [3–6]. In the case of the use of ELA, the high

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doi:10.1016/j.tsf.2006.11.146

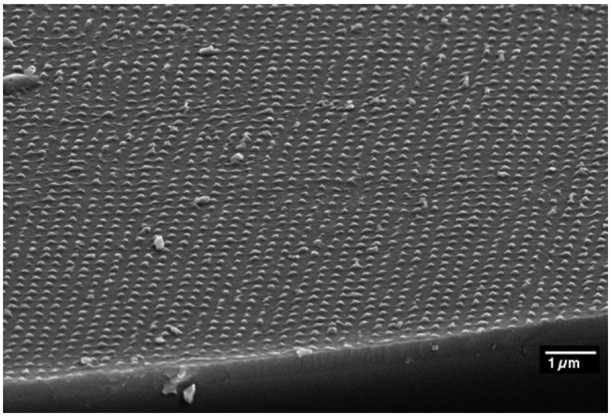

Fig. 1. SEM micrograph of the poly-Si surface crystallized by using ELA.

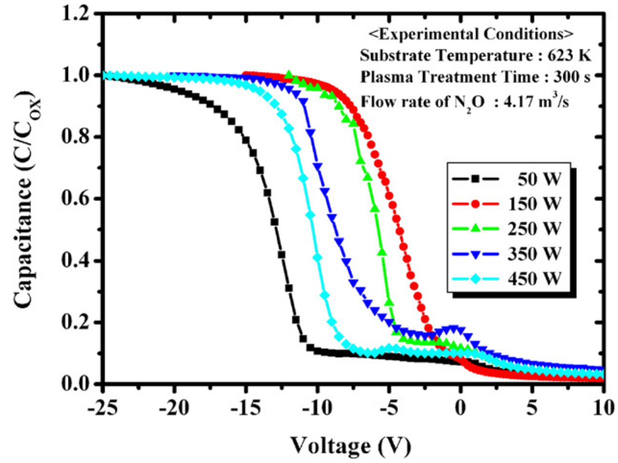

Fig. 2. The capacitance–voltage (C–V) characteristics of MOS structures using ultra-thin SiO*x*N*y* films grown by varying RF power as gate insulator. The electrical C–V measurements are performed by voltage sweep from inversion (+V) to accumulation (−V).

surface roughness is found due to melting/crystallization of substrate during irradiation of laser beam. The SEM micrograph of the poly-Si surface structures obtained by using ELA is shown in Fig. 1. Since the general chemical vapor deposition (CVD) cannot generate uniform thickness of tunnel oxide for the fabrication of NVM, plasma-assisted oxidation/nitridation method is applied to form uniform tunneling layer.

During the last decade, oxynitride thin films were intensively investigated as a high-quality gate dielectrics [7,8]. The incorporation of nitrogen at the Si–SiO_2 interfaces reduces tunneling current and defect generation, and in bulk, nitride allows the use of physically thicker films without reduced capacitance compared to single-layer oxide. For this study, we fabricated ultra-thin oxynitrided tunneling layer using nitrous oxide (N_2O) plasma by inductively coupled plasma-CVD (ICP-CVD) in LTPS-TFT for NVM application. Such a device could be used in flat panel display because the surface roughness of LTPS formed by using ELA was overcome for the fabrication of the LTPS NVM. The fabricated metal-insulator-semiconductor (MOS) under optimal condition showed sufficient electric stability and electrical characteristics of a tunneling layer.

2. Experimental

In this experiment, (100) oriented, p-type single crystalline silicon substrate was used for the fabrication of MOS capacitors. Before N_2O plasma treatment, the silicon wafers were cleaned using a H_2SO_4: H_2O_2 (4:1 at 363 K for 600 s) solution followed by a dip in a 10% HF solution to remove the silicon oxide formed in the piranha cleaning. After drying with nitrogen gas, the wafer was immediately transferred into the chamber for plasma treatment. Silicon wafers were then oxynitrided by N_2O plasma exposure under different radio frequency (RF) powers by ICP-CVD. During plasma treatment, N_2O flow rate was maintained to be 4.17 m^3/s and the working pressure in the discharge chamber was 0.147 Pa. The layers of silicon oxynitride (SiOxNy) were also created by varying the time for N_2O plasma treatment to analyze the thickness and properties of oxynitrided film under optimized conditions of RF power, flow rate, and substrate temperature at 150 W, 4.17 m^3/s, and 623 K. The applied RF was 13.56 MHz through a matching network to a coil.

The thickness and refractive index of ultra-thin oxynitrided films were measured by ellipsometer using 1.95 eV light. For the analysis of chemical composition in oxynitrided layer, the X-ray energy dispersive spectroscopy (EDS) was used. An Aluminum electrode of area 4.91×10^{-8} m^2 was formed for the MOS capacitor by evaporation. Then the high frequency (1 MHz) capacitance–voltage (C–V) characteristics of the fabricated MOS were investigated. Dielectric constants were calculated from electrical measurement using these capacitors. Metal-oxide-nitride-oxide-semiconductor (MONOS) devices were fabricated for the measurement of its function as a tunneling oxide of ultra-thin SiO*x*N*y* layer using N_2O plasma treatment. Silicon nitride (SiN*x*) with refractive index of 2.13 and thickness of 22.5 nm was deposited to use as a charge trap region on ultra-thin SiO*x*N*y* layer and silicon dioxide (SiO_2)

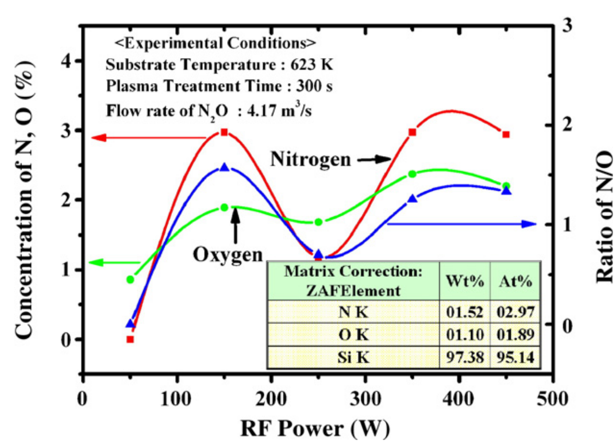

Fig. 3. Composition and EDS analysis of every ultra-thin SiO*x*N*y* films grown by varying RF power. The inset shows weight percentage and atomic percentage of the original spectrum obtained by EDS about the ultra-thin SiO*x*N*y* film fabricated by using RF power, flow rate of N_2O, substrate temperature, and plasma treatment time of 150 W, 4.17 m^3/s, 623 K, and 300 s.