



FT-IR spectrum study for a silicon dioxide thin film prepared by laser oxidation

Laith M Al Taan ^{1*}, Mohand M Alyass ²

^{1,2} Department of Physics, College of Science, Mosul University, Iraq

* Corresponding Author: **Laith M Al Taan**

Article Info

ISSN (online): 2582-7138

Volume: 03

Issue: 04

July-August 2022

Received: 21-07-2022;

Accepted: 13-08-2022

Page No: 22-25

Abstract

A thin film insulating SiO₂ was prepared using a laser oxidation technique. The growth of the dioxide layers and the interface Si/SiO₂ were studied by analyzing the absorption spectrum through an FT-IR spectrometer. The results show a characteristic sharp peak at the wave number (1079 cm⁻¹) corresponds to the level of elongate ion vibrations (Si-O-Si) which consists of required oxide. The shoulder region appeared at the wave number (1200cm⁻¹) which indicates that the silicon atom was moving in the opposite direction of an oxygen atom. The increase in temperature leads to reducing the absence of the entropy in the composition of SiO₂. The different times for the oxide configuration give a different value for the capacity where the highest capacity was created for the longest time, that the oxide thickness has an inverse relationship with the time of laser induction of the oxidation.

Keywords: FT-IR spectrum, oxidation, dioxide

1. Introduction

The properties of silicon dioxide that make it ideal for MOSFETs are numerous. SiO₂ has a wide bandgap, 9eV, which makes it a very good insulator between the gate of the device and the channel. This insulating property is very important to prevent current leakage from the gate into the channel. The insulating properties of SiO₂ are maintained even at high fields (SiO₂ has a breakdown field of about 15 MV/cm) allowing very thin films to be used. SiO₂ also has a low bulk fixed charge density, [Mohand and Al Taan, 2017] ^[6].

Another important feature of SiO₂ is that it has good stability in the bulk of the film and at the interface to silicon over a wide range of thermal and electrical stressing conditions. This means that as a device is operated in a changing environment its properties will remain constant, [Demakov and Navrotsky, 2005]. Silica films can be deposited on silicon wafers by CO₂ laser-assisted CVD with high quality, adherent, dense and stoichiometric. The laser oxidation and Infrared spectra of photochemical grown sub-oxides at the Si/SiO₂ interface can be an interpretation of these features as superimposed individual suboxide TO-phonon bands provide important insight into the first stages of photoinduced silicon oxidation. [Lambers and Hess, 2003] ^[3]. In this study, the CO₂ laser was used to form the SiO₂ insulator, with continuous operational power (watt 80) and wavelength (10.6μm) in a rich environment of oxygen and water vapor. This formed insulator was analyzed by (FT-IR) technology, to study the mechanism of oxide layer formation by this method.

2. The Experimental and Martials

The Si substrate was prepared and cleaned using hydrofluoric acid diluted to 10% for 5 minutes and methanol for 5 minutes finally wash the slides with distilled water and dried, then the silicon was checked using warming palpation, and then complete the following steps.

2.1 The oxidation

The silicon Si (111) slides were placed on the Pyrex glass inside the crucible, and put (NaCl) crystal close the room. Run the laser device to (10 mA), which corresponding to (22 watts).

The emitted laser beam from a CO₂ laser falls on the copper mirror and reflected at an angle of 45°, to enter the crucible through a crystal NaCl and fall on the form, which in turn absorbs part of the energy, where the remaining energy-absorbing by Pyrex glass. It proves that the high temperature is a key factor for the modified high CO₂ laser absorption of Si. Since Si has a high thermal conductivity of 150 W/(m-K) for solid (300 K) and 450 W/(m-K) for liquid (1685 K) [Chung, 2007]^[1].

2.2 FT-IR technology

The Silicon samples were analyzed to know the quality and quantity of oxide formed using a FT-IR, which is connected with the analyzed software, as follows.

Get rid of the background for the relative analysis. After

cleaning the silicon samples, these samples are placed inside the chamber which is designed for this purpose, and the analysis absorption spectrum of these samples was taken. The oxidizing samples were also analyzed with the absorption spectrum. Then extract the absorption spectrum of the SiO₂ insulator curves of oxidized and from that which is non-oxidized.

3. Results and Discussions

3.1 FT-IR spectrum of p-Si (111)

Figure (1) shows the appearance of a peak at the wave number between (1080-1070 cm⁻¹), and this indicates the presence of the (Si-O) bond when, despite careful cleaning, the presence of the oxide indicates that the silicon is oxidizing even minutes before the oxidation process.

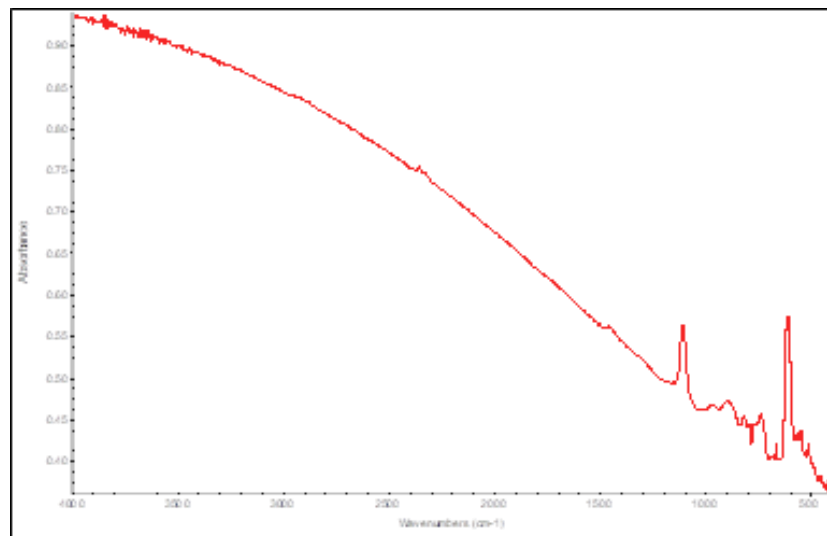


Fig 1: IR Spectrum for p-Si (111)

The oxidation of the surface of silicon naturally is due to two reasons: The used silicon of type Si (111), which is known to have many suspended bonds at the interface, compared to silicon Si(100), which has fewer bonds. Helps naturally oxidize the surface. The second reason is that during the cleaning process or after it, silicon becomes more effective in oxidizing oxygen molecules in the atmosphere. Studying the oxide formed accurately by known oxidation methods requires getting rid of the formed natural oxide, but it is

difficult to get rid of this oxide even under ideal conditions or in the so-called clean room, so (Si-O) bonds appear.

3.2 FT-IR spectrum of the Si/SiO₂ interface formed by laser-induced oxidation

Figure (2) shows a model of silicon one that is oxidized at some point and here it shares the natural oxide with it. The shape of this spectrum is almost repeated each time.

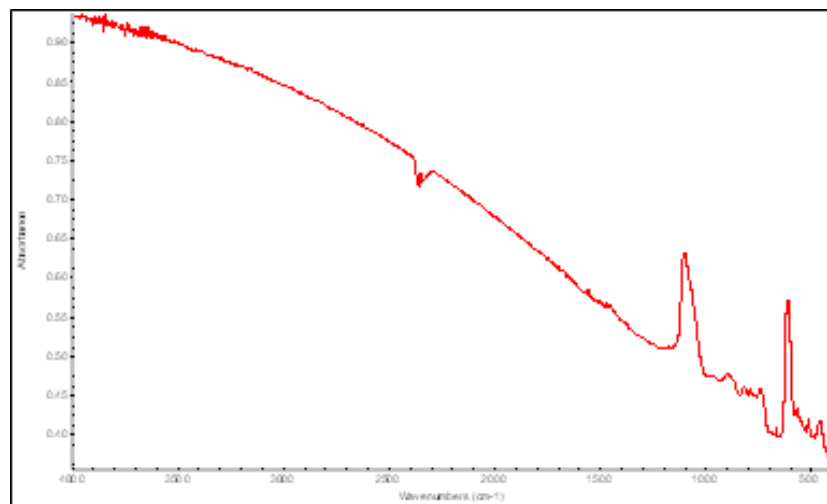


Fig 2: The FTIR spectrum Si/SiO₂ interface

From the spectral figure above (a noticeable increase in the height of the peaks and at the number is observed. The wave number ($1080\text{-}1070\text{ cm}^{-1}$), is due to the formation of a film of SiO_2 resulting from shining laser beams (CW- CO_2) on the surface of the silicon by the availability of oxygen gas and water vapor by a method called (wet oxidation) and at a temperature of (600C°). As well as the appearance of bonds at wave number (600 cm^{-1}), which goes back to Si-Si bonds.

3.3. FT-IR spectrum of a SiO_2 thin-film formed by laser-induced oxidation

The following figures (3) and (4) are, for the absorption spectra of SiO_2 films prepared by the laser oxidation technique, formed at different SiO_2 insulator growth times, which were extracted by the FT-IR technique by removing the native oxide from the calculations, and this process is very accurate to study the SiO_2 layer formed at different times, And to know the exact amount of insulator emerging.

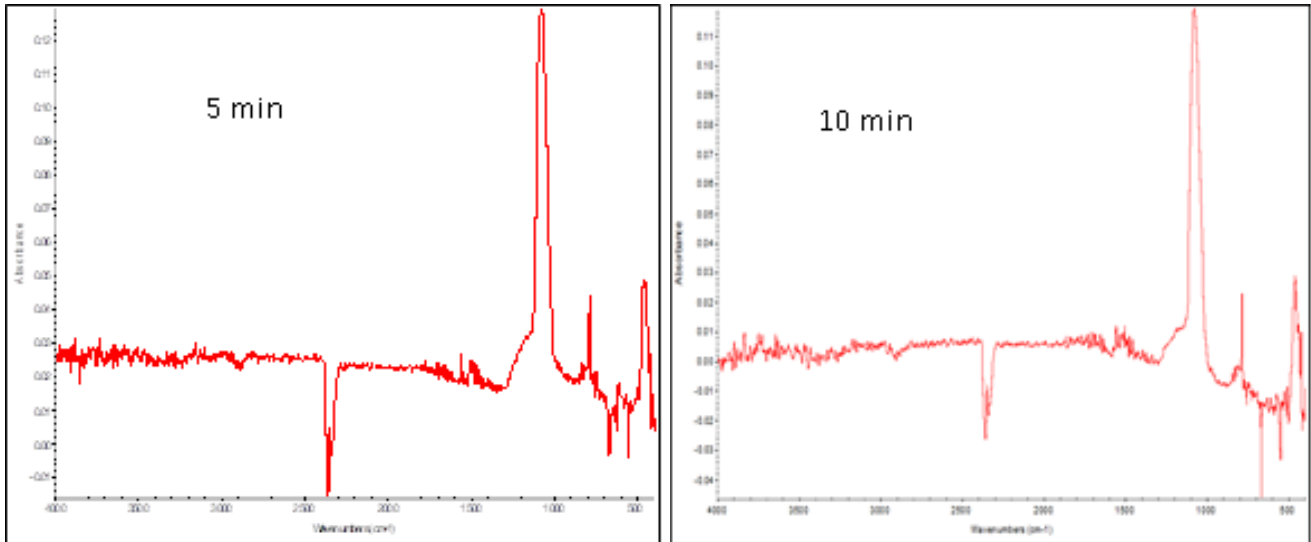


Fig 3: FTIR for SiO_2 film formed at (5min) and (10 min) of growth time

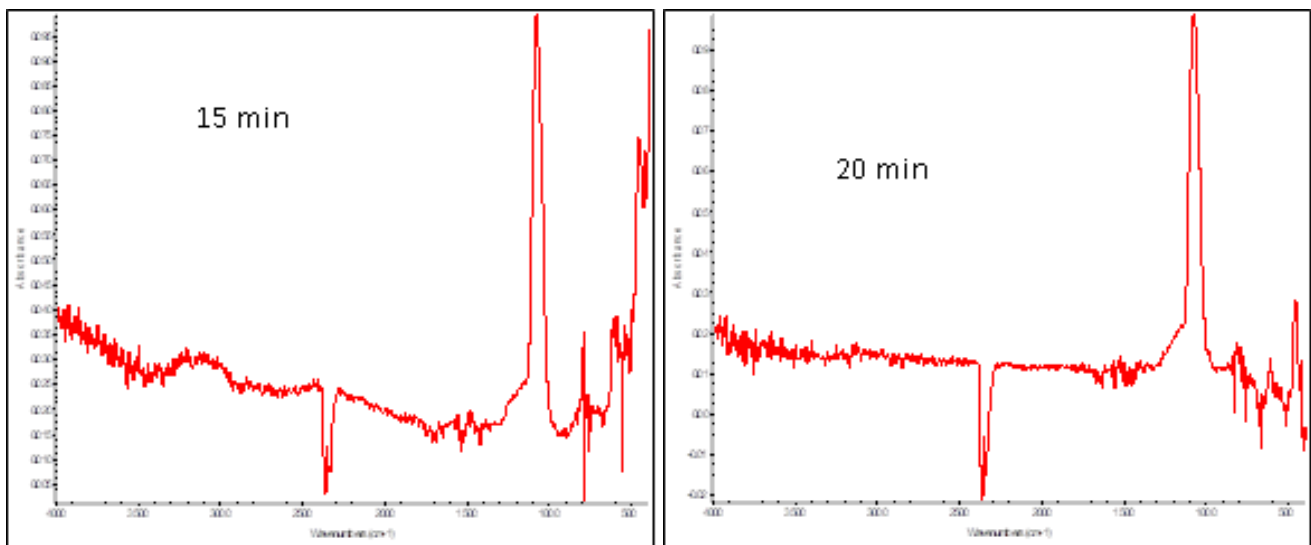


Fig 4: FTIR for SiO_2 film formed at (15min) and (20min) of growth time

Figures (3) and (4) represent the actual absorption spectrum of SiO_2 film, resulting from oxidation using CO_2 (CW) lasers, showing that the absorption spectrum of the recorded FT-IR was a spectrum extending from ($4000\text{-}600\text{ cm}^{-1}$).

4. Conclusion

As the IR spectrum extending from ($1350\text{-}950\text{ cm}^{-1}$) for all the above figures, it appears that the models have (Si-O-Si) bonds [Lambers and Hess, 2003] [3], and it indicates three important properties in IR bonds, which are:

1. There is a sharp peak at the wave number $\sim 1079\text{ cm}^{-1}$, and this agrees with [Tsuji *et al.*, 1991] [8], [Takao *et al.*, 2007] [7]. This sharp peak corresponds to the elongation

vibration in which the oxygen atoms move in the (Si-O-Si) plane along the line connecting the two silicon atoms] [Lucovsky and Irene, 1987. [Lambers and Hess, 2003] [4, 3].

2. It is noticed that there are no absorption peaks at the wave number (950 cm^{-1}), which confirms that this region of the spectrum is free of (Si-OH) bonds [Maruyama and Shirai, 1993] [5].
3. The presence of a region called (the shoulder region), at the wave number ($\sim 1200\text{ cm}^{-1}$), indicates that the silicon atom will move in an opposite direction to the oxygen atom [Hess and Lambers, 2004] [2].

It is also shown in Figures (3) and (4) that at the sharp peak (~ 1079) cm^{-1} zigzags appear, and it is believed that the cause of these zigzags is caused by several stages of oxidation and that the structural defects affected the final stages of the appearance of the absorption spectrum and led to the creep. The curve ranged from a value less than (~ 1079) cm^{-1} , and this is in agreement with the researchers [Lambers and Hess, 2003]^[3], as the curves of the above figures are the last distinct oxidation process at a particular time.

References

1. Chung CK, Wu MY. A hybrid CO₂ laser processing for silicon etching. *J. Optics Express*. 2007; 15(12):7269-7274.
2. Hess P, Lambers J. Infrared spectra of photochemically grown suboxides and oxynitrides at the Si/SiO₂ interface. *J. Microelectronic Engineering*. 2004; 72:201-206.
3. Lambers J, Hess P. Infrared spectra of photochemically grown suboxides at the Si/SiO₂ interface. *J Appl. Phys*. 2003; 94(5):2937-1341.
4. Lucovsky G, Irene MJ. Low-temperature growth of silicon dioxide: a study of chemical bonding by ellipsometry and infrared spectroscopy. *J Vac. Sci. Technol. B*, 1987, 5(2).
5. Maruyama T, Shirai T. Silicon dioxide thin film transistor from tetramethylsilane silicon dioxide and sputtered silicon. Ph. D. Thesis, the Pennsylvania State University, U.S.A, 1993.
6. Mohand M Alyass, Al-Taani LM. The Effect of Si/SiO₂ Interface on the Electrical Properties of MOS Device with Nano Layer Silicon Dioxide Grown by Induced Laser Oxidation *J Raf. Sci*. 2017; 26(1):101-112.
7. Takao H, Okoshi M, Inoue N. Wavelength dependence on the formation of SiO₂ films by ultraviolet-laser-induced photochemical deposition using silicone rubber. *J. Conference Series*. 2007; 59:432-435.
8. Tsuji M, Sakumoto M, Itoh N, Obase H, Nishimura Y. SiO₂ films growth by ArF laser photolysis of SiH₄/N₂O mixtures. *J Appl. Surf. Sci*. 1991; (51):171-176.