SURFACE MORPHOLOGY, OPTICAL AND ELECTRICAL PROPERTIES OF POROUS SILICON PRODUCED BY CHEMICAL ETCHING

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DEDICATION

to my family members and friends who has always encouraged me to do the best and supported me wholeheartedly in everything I pursued

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In past decades, silicon is commonly used in the semiconductor industry. Recently, researcher extensively studied the porous silicon produced by electrochemical etching because there is possibility to develop a new approach in developing optoelectronic devices, solar cell and sensor. In this research, the Porous Silicon (PS) was fabricated by chemical etching method on the P-type silicon wafer in the mixture of hydrofluoric acid (HF) etchant with different concentration of nitric acid (HNO_3) of 20%, 40%, 65% and at different etching time of 5, 10, 15, 20, 25 minutes. The surface morphology of PS was studied by SEM (Scanning Electron Microscope), AFM (Atomic Force Microscope) and FE-SEM (Field Emission Scanning Electron Microscope), where it shows that it has crystallites structure

surrounded with pores. The crystallites structure size decreases as etching time increase and the crystallites size for PS prepared with 20%, 40% and 65% HNO_3 concentration are in the range of ~250-280 nm, ~500 nm and ~200-600 nm respectively. While the pores size for PS prepare by 20%, 40% and 65% HNO_3 are in range of ~20-150 nm, ~20-100 nm and ~10-100 nm respectively. Pores size reduces with the increase of HNO_3 concentration. The elemental analysis on the surface of PS was characterized by Energy Dispersive Spectroscopy (EDS) and it shows that it contain Silicon and Oxygen element. Thus, it can be deduced that the surface species contain Si-O bonds.

The porosity for PS prepared by 20%, 40% and 65% HNO_3 was determined by gravimetric method and was in range of 19-30 %, 38-60 % and 49-80 % respectively. The porosity linearly increase with etching time and HNO_3 concentration. Photoluminescence (PL) of PS were in the range of 617-642 nm, 657-660 nm and 640-636 nm for PS with 20%, 40% and 65% HNO_3 respectively. All the PS gives orange-red photoluminescence. Blue shift effect was observed on PL spectrums for all type of concentration of HNO_3 when the etching time increases. The highest energy gap obtained was 2.01 eV and the lowest was 1.902 eV. All three different concentrations of HNO_3 show that the PL peak intensity of PS increases as etching time increase. From the electrical conductivity analysis, it shows that the porous silicon conductivity increases from PS prepared with concentration of 20% HNO_3 (5.089×10^{-9} - 9.624×10^{-6} $(\Omega\cdot cm)^{-1}$) to 65% HNO_3 (1.323×10^{-7} - 4.299×10^{-6} $(\Omega\cdot cm)^{-1}$) and lastly 40% HNO_3 (3.113×10^{-5} - 0.015 $(\Omega\cdot cm)^{-1}$) when the energy gap reduces. The conductivity decreases as the porosity, surface roughness and energy gap increases.

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KAJIAN MORFOLOGI PERMUKAAN, OPTIK DAN ELEKTRIK SILIKON POROS YANG DIHASILKAN DENGAN KAEDAH PUNARAN KIMIA

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Beberapa dekad yang lepas, silikon banyak digunakan dalam industri semikonduktor. Baru-baru ini, silikon poros yang dihasilkan dengan teknik punaran elektrokimia telah dikaji dengan lebih mendalam oleh penyelidik kerana terdapat kemungkinan untuk menghasilkan satu pendekatan baru dalam menghasilkan alat-alat optoelektronik, sel suria dan penderia. Dalam penyelidikan ini, silikon poros (PS) dihasilkan dengan kaedah punaran kimia pada silikon wafer jenis-P dengan mencelupnya dalam bahan punar terdiri daripada campuran asid hidrofluorik (HF) bersama asid nitrik (HNO_3) yang berbeza kepekatan (20%, 40% dan 65%) dengan masa punaran yang berbeza 5, 10, 15, 20, 25 minit. Morfologi permukaan PS dikaji dengan SEM (Mikroskop Elektron Imbasan), AFM (Mikroskop Daya Atom) dan FE-

SEM (Medan Pancaran Mikroskop Elektron Imbasan), di mana ia menunjukkan bahawa permukaan PS mempunyai hablur-hablur yang dikelilingi oleh liang-liang. Saiz hablur berkurang apabila masa punaran meningkat. Saiz hablur untuk PS yang disediakan dengan kepekatan 20%, 40% dan 65% HNO_3 adalah berada dalam julat ~250-280 nm, ~500 nm dan ~200-600 nm masing-masing. Manakala saiz liang untuk PS yang disediakan dengan kepekatan 20%, 40% dan 65% HNO_3, berada dalam julat ~20-150 nm, ~20-100 nm dan ~10-100 nm masing-masing. Peningkatan kepekatan HNO_3 telah menyebabkan saiz liang berkurang. Unsur di permukaan PS dianalisiskan dengan EDS (Spektrometer Serakan Tenaga), dimana ia menunjukkan permukaan PS mengandungi unsur Silikon and Oksigen. Oleh itu, spesies ikatan di permukaan PS mengandungi ikatan Si-O.

Keporosan untuk PS yang disediakan dengan 20%, 40% dan 65% HNO_3 telah ditentukan dengan kaedah gravimetri dan keporosan PS adalah berada dalam julat 19-30 %, 38-60 % dan 49-80 % masing-masing. Keporosan meningkat secara linear terhadap masa punaran dan kepekatan HNO_3. Kefotopendarcahayaan (PL) dari PS telah diukur oleh spektrometer fotopendarcahaya dan puncak PL kepada PS yang disediakan dengan 20%, 40% dan 65% HNO_3 berada dalam julat 617-642 nm, 657-660 nm dan 640-636 nm masing-masing. Semua PS menghasilkan fotopendarcahaya jingga-kemerahan. Anjakan biru di puncak PL dapat diperhatikan pada spektrum PL untuk semua jenis kepekatan HNO_3 apabila masa punaran bertambah. Jurang tenaga tertinggi yang diperolehi adalah 2.01 eV dan yang terendah adalah 1.902 eV. PS yang dihasilkan dengan kepekatan HNO_3 yang berbeza menunjukkan bahawa keamatan puncak PL bersandar dengan masa punaran. Analisis kekonduksian elektrik menunjukkan kekonduksian PS meningkat dari PS yang disediakan dari

kepekatan 20% HNO_3 (5.089×10^{-9} - 9.624×10^{-6}) $(\Omega.cm)^{-1}$ ke 65% HNO_3 (1.323×10^{-7} - 4.299×10^{-6}) $(\Omega.cm)^{-1}$ dan akhirnya 40% HNO_3 (3.113×10^{-5} - 0.015) $(\Omega.cm)^{-1}$ apabila jurang tenaga berkurangan. Kekonduksian PS berkurang apabila keporosan, kekasaran permukaan dan jurang tenaga meningkat.