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STRUCTURAL, OPTICAL AND THERMAL PROPERTIES OF AS-PREPARED AND ANNEALED GOLD COATED POROUS SILICON

KASRA BEHZAD

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STRUCTURAL, OPTICAL AND THERMAL PROPERTIES OF AS-PREPARED AND ANNEALED GOLD COATED POROUS SILICON

By

KASRA BEHZAD

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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I dedicate this thesis to my wife, parents, sisters, brother and my daughter Andia for nursing me with affections, love and their dedicated partnership for success in my life.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

STRUCTURAL, OPTICAL, AND THERMAL PROPERTIES OF AS-PREPARED AND ANNEALED GOLD COATED POROUS SILICON

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Chairman: Professor Wan Mahmood Mat Yunus, PhD

Faculty: Science

In this study, porous silicon (PSi) layers were prepared on n-type silicon (Si) substrates using the anodization method. Three sets of PSi samples were prepared under different current densities (10, 20, and 30 mA/cm^2), where each set consisted of six samples that were prepared at different etching times (10, 20, 30, 40, 50, and 60 min). Gold was coated at different thicknesses (5, 10, and 20 nm) on PSi, Si, and glass substrates. Gold coated porous silicon (Au/PSi) with 20-nm thick gold layers, were selected for annealing at different temperatures (360, 600, 800, and 1000 °C).

The structural characterizations were performed by gravimetrical method, Field Emission Scanning Electron Microscope (FESEM), and Energy Dispersive X-Ray Analyser (EDX). The porosity initially increased and then leveled off after attaining a certain value (47%–94%), but the thickness increased linearly with an increase in the etching time and current density (3.8–104 μm). For PSi samples, FESEM images showed that pores were formed on the surface. In the Au/PSi samples, a thin film of Au was coated on the porous structure. In the annealed Au/PSi samples, after annealing at a temperature higher than 360 °C, the surface of the samples were covered by silicon nanorods (SiNRs). The length of these nanorods varied between 110 and 1500 nm, and their diameter was tuned from 60 to 106 nm.

Photoluminescence (PL) and photoacoustic spectroscopy (PAS) were carried out as optical characterizations. PL spectra show a peak for PSi and Au/PSi samples that is blue shifted towards higher energy, in the range of 700 to 600 nm, as the porosity is increased from 47% to 94%. The intensity of PL peaks raised around 50% by increasing the porosity and decreased (92 to 98%) by coating the gold layer (5 to 40 nm). The absorbance spectra achieved by PAS at modulation frequency of 73 Hz. It shows that the optical absorption raised by increasing the porosity. Gold deposition increased the absorbance and also pushed them up in the range of 500-800 nm. The band gap was calculated from PL and PA spectrum

and the results are in good agreement with each other. The band gap increased linearly from 1.76 to 2.15 eV with porosity.

Thermal characterization was fulfilled by PAS with chopping frequency, 20-240 Hz. The thermal diffusivity (TD) measured for PSi, Au/PSi and annealed Au/PSi samples. The TD reduced (0.33-0.08 cm^2/s) with raising the porosity due to limitation of phonon mean free path. By gold deposition due to the additional metal layer, the TD increased to more than 25-38% of the PSi. After annealing the Au/PSi samples the TD decreased to the lowest value (0.23 to 0.27 cm^2/s) at 360 ^oC. By growing the nanorods the TD increased (0.4 to 0.53 cm^2/s) at 600 ^oC to the maximum value. It decreased (0.36 to 0.50 cm^2/s) by increasing the annealing temperature to 800 and 1000 ^oC.

Based on the first objective of dissertation; PSi samples were prepared, deposited and annealed under different conditions. By following the next three objectives, the structural, optical, and thermal investigations have been done on the samples to find the applicable applications for these samples. These investigations promote a novel field of study and can extend the applications of PSi as an interesting material in the nanotechnology and optoelectronics fields.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

STRUKTUR, SIFAT OPTIK DAN TERMA SILIKON TERSEDIA DAN ANIL EMAS BERSALUT SILIKON BERLIANG

Oleh

KASRA BEHZAD

Dicember 2012

Pengerusi: Profesor W. Mahmood Mat Yunus, PhD

Fakulti: Sains

Dalam kajian ini, lapisan berliang silikon (PSi) telah disediakan keatas substrat silikon jenis-n (Si) dengan menggunakan kaedah penganodan. Tiga set sampel PSi telah disediakan di bawah ketumpatan semasa yang berbeza (10, 20, dan 30 mA/cm^2), di mana setiap set terdiri daripada enam sampel yang telah disediakan pada masa punaran yang berbeza (10, 20, 30, 40, 50, dan 60 minit). Emas disalut berbeza ketebalan (5, 10, dan 20 nm) pada PSi, Si, dan substrat kaca. Silikon berliang bersalut emas (Au/PSi) dengan lapisan emas yang bertebalan 20 nm, telah dipilih untuk penyepuhlindapan pada suhu yang berbeza (360, 600, 800, dan 1000 ° C).

Pencirian fizikal telah dilakukan dengan mengukur keliangan, ketebalan, mikroskop pengimbas elektron pancran medan (FESEM) dan spektroskopi sinar-X penyebar tenaga (EDX). Keliangan pada mulanya meningkat dan kemudian mendatar selepas mencapai nilai tertentu (47% - 94%), tetapi ketebalan meningkat secara linear dengan peningkatan dalam masa punaran dan ketumpatan semasa (3.8-104 μm). Bagi sampel PSi, imej FESEM menunjukkan bahawa liang telah terbentuk di permukaan. Dalam sampel Au/PSi, filem nipis Au disalut pada struktur berliang. Dalam sampel Au/PSi disepuh lindap, selepas penyepuhlindapan pada suhu yang lebih tinggi daripada 360 °C, permukaan sampel telah dilindungi oleh nanorod silikon (SiNRs). Panjang nanorod ini adalah berbeza-beza antara 110 dan 1500 nm, dan diameternya telah siap sedia antara 60-106 nm.

Fotopenyinaran (PL) dan spektroskopi fotoakustik (PAS) yang telah dijalankan sebagai pencirian optik. PL spektrum menunjukkan puncak bagi PSi dan Au / PSi sampel yang biru beralih ke arah tenaga yang lebih tinggi, dalam lingkungan 700-600 nm, apabila keliangan meningkat daripada 47% kepada 94%. Keamatan puncak PL menaik sekitar 50% dengan meningkatkan keliangan dan menurun (92-98%) oleh salutan lapisan emas (5-40 nm). Spektrum keserapan yang dicapai oleh PAS pada frekuensi pemodulatan 73 Hz. Ia menunjukkan bahawa penyerapan optik yang dibangkitkan oleh peningkatkan keliangan. Pemendapan emas meningkat keserapan dan juga menolak mereka dalam julat 500-800 nm.

Jurang jalur dikira dari spektrum PL dan PA dan keputusan adalah di dalam perjanjian yang baik. Jurang jalur meningkat secara linear dari 1.76 2.15 eV dengan keliangan.

Pencirian terma telah dipenuhi oleh PAS dengan frekuensi mencincang, 20-240 Hz. Kemeresapan terma (TD) diukur untuk PSI, Au / PSI dan sepuhlindap sampel Au/PSi. TD berkurangan (0.33-0.08 cm^2/s) dengan meningkatkan keliangan yang disebabkan kepada had fonon laluan bebas. Disebabkan oleh pemendapan emas oleh lapisan logam tambahan, TD meningkat kepada lebih daripada 25-38% daripada PSi. Selepas penyepuhlindapan sampel Au/PSi TD berkurangan kepada nilai yang terendah (0.23-0.27 cm^2/s) pada 360 ^oC. Dengan pertumbuhan nanorods TD meningkat (0.4-0.53 cm^2/s) pada 600 ^oC kepada nilai maksimum. Ia menurun (0.36-0.50 cm^2/s) dengan meningkatkan suhu penyepuhlindapan 800 ^oC dan 1000 ^oC.

Berdasarkan sampel objektif pertama disertasi; silikon berliang (Psi) telah disediakan dengan didepositkan dan disepuh lindap di bawah keadaan yang berbeza. Tiga objektif seterusnya adalah penyelidikan terhadap struktur, optik, dan terma telah dilakukan ke atas sampeluntuk mencari aplikasi yang boleh diguna pakai untuk sampel ini. Penyelidikan ini menggalakkan satu bidang kajian novel dan boleh memanjangkan aplikasi PSI sebagai bahan yang menarik dalam bidang nanoteknologi dan optoelektronik.

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I certify that a Thesis Examination Committee has met on 21 December 2012 to conduct the final examination of Kasra Behzad on his (or her) thesis entitled "Structural, optical and thermal properties of as-prepared and annealed gold coated porous silicon" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.

KASRA BEHZAD

Date:

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