



A study on Optical Properties of porous silicon with different methods

MR ANSHU KUMAR TRIPATHI

ACADEMIC HEAD

SUNBEAM SUNCITY (SCHOOL & HOSTEL) VARANASI 221011

Abstract— Because silicon is a semiconductor element with a well-established and reasonably inexpensive technology, crystalline, microcrystalline, and amorphous silicon have been playing a highly essential role in many aspects of fundamental and applied research disciplines. However, due to its 1.1 eV energy gap, silicon was not used in optoelectronics until recently. Instead, compound semiconductor technologies—which are typically very expensive and difficult to use—were used instead. Much curiosity was sparked when it was discovered that porous silicon (PS) could exhibit visible electroluminescence even at ambient temperature. Otto, micro, and nano-electronics are just a few of the additional application domains made possible by this semiconductor, which has an energy gap that is 0.5 eV larger than that of its crystalline predecessor.

Keywords— Porous Silicon (PS), Optical Properties, Etching time.

I. INTRODUCTION

The material constants that characterize mechanical qualities that may have variable values with respect to porosity are Young's modulus, Poisson's ratio, shear modulus, and bulk modulus. Consequently, the mechanical characteristics of porous silicon are being studied in order to appropriately design devices made of such anisotropic silicon-based materials and for which such mechanical features are crucial.

The transverse, longitudinal, and Rayleigh velocities (V_T , V_L , and V_R , respectively), longitudinal impedance (Z_L), and transverse impedance (Z_T) are the acoustic parameters that can be studied. Numerous attempts to determine how porosity (P) is dependent on various acoustic characteristics have been documented in the past with regard to specific materials [1-3]. Therefore, studying porosity is crucial to determining material properties, and understanding elastic constants and associated attributes is essential to using electroluminescent devices. The elastic and acoustic properties of the porous silicon are particularly relevant to this aim.

Porous silicon's refractive index is expected to be lower than that of bulk silicon because it is a mixture of silicon and air, and it depends on how porous that specific layer is. The refractive index of the PS obviously reduces as the ratio of silica to air decreases, which is to say, as porosity increases. A lot of work has been done to establish a straightforward link between the refractive index and the energy gap [4-7].

II. LITERATURE SURVEY

We will first discuss general aspects seen in theories for the elasticity of cellular materials in order to comprehend the porosity and the energy gap dependency of the elastic properties of PS. We demonstrate how the porosity dependence of the elasticity can be integrated into the presentation of an anisotropic material. These theories are generally semi-empirical for PS, which maintains its c-Si lattice structure in the solid skeleton around the



International Journal of Recent Development in Engineering and Technology

Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 13, Issue 3, March 2024)

pores. Numerous writers have made significant attempts to investigate the thermodynamic characteristics of solids [8–12]. The writers of these works have looked at the thermodynamic characteristics of solids with various approximation and best-fit relations, including the bulk modulus and the inter-atomic separation. A significant number of the structural and electrical properties of solids may now be computed with high accuracy. The calculations for abolition are intricate and demand a lot of work. In order to calculate the properties of materials, additional empirical techniques have been devised [12, 13]. The capacity to apply empirical approaches to a wide range of materials and to show trends is frequently an advantage. These empirical methods are nonetheless quite helpful in many applications, even though they don't always produce extremely exact findings for each particular material. An empirical formula for calculating the bulk modulus B based on the nearest-neighbor distance has been established by Cohen [14]. His results don't match the values from the experiment. An analytical equation for the bulk modulus derived from the total energy was obtained by Lam et al. [15]. Although this expression's structure differs from the empirical formula's, it produces outcomes that are numerically comparable. They have also managed to derive an analytical expression for the bulk modulus's pressure derivative B . This theory produces a formula with two appealing features. The computation of B itself is simple; only the lattice constant needs to be provided as input. To apply this method practically, one must take into account a hypothetical structure and simulate the experimental conditions. The goal is to determine the relationship between the energy gap and porosity of PS and qualitative concepts such as the bulk, shear, young's, and plane moduli. It was suggested that the primary effect is the degree of covalence defined by the Phillips homopolar gap E_h [16], and the fact that the calculations' validity is unrestricted in calculated space is one of the reasons these data are presented in this work.

Ultrasonic nondestructive evaluation techniques, which involve measuring wave velocities, are among the most difficult approaches for characterizing thin films, coatings, and bulk materials. The following relationship can be used to analyze the acoustic characteristics, such as longitudinal

impedance, transverse impedance (Z_L , Z_T), and Rayleigh velocities (V_T , V_L , and V_R , respectively), as well as the elastic constants. The porous nature ascertains the sample's density (ρ) and acoustic velocities (v), which together establish the acoustic impedance $Z = \rho v$. The PS model consists of two isotropic components: a silicon shell and pores that have diameters significantly smaller than the wavelength of light (λ). As a result, PS can be thought of as an effective refractive index (n) optically isotropic medium. It has a n that is greater than air and lower than silicon, which is a consequence of porosity.

III. EXPERIMENTAL ANALYSIS

The threshold for photon absorption in semiconductors is established by the energy gap, and the transparency of the material to incident spectrum radiation is indicated by its refractive index (n). Regarding microscopic atomic interactions, the " n " is a significant physical quantity. The local polarizability of these things and the refractive index related to density are theoretically two alternative ways to look at this topic [17]. However, there will be a close relationship between the crystalline structure, as represented by a delocalized image and refractive index, and the material's energy band structure, complex quantum mechanical analytical requirements, and the acquired results.

The dielectric constant (ϵ) and current density (n) for various polymer concentrations, etching times, and current densities have been estimated through the utilization of five theoretical models and effective medium approximation methods [18].

IV. CONCLUSION

To conclude, the work utilized five theoretical models and the effective medium approximation methods to determine the dielectric constant (ϵ) and refractive index (n) for different polymer concentrations, etching periods, and current densities in porous silicon (PS) samples. Lower values were seen in PS samples, especially as the percentage of porosity increased, but overall, the results were in good agreement with experimental data for bulk silicon. When considering how current density affects things, it was observed that both



International Journal of Recent Development in Engineering and Technology

Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 13, Issue 3, March 2024)

'n' and 'ε' decreased with increasing current density with a slight increase.

When examining various etching times while maintaining a constant current density, a similar pattern was found. With longer etching times (10–40 min), 'n' and 'ε' declined, and at 50 min, there was a tiny increase. Yet, they started to decline once more after 60 minutes, suggesting preformation in the c-Si wafer underneath. The observed effects on c-Si with varied current density were in line with these tendencies. 'n' and 'ε' showed an opposite trend to the effects of current density and etching time in the case of PS treated with polymers. Higher 'n' and 'ε' values were obtained with increasing polymer concentrations (0.5%, 0.75%, and 1.0%) as a result of a decrease in porosity. The infiltration of polymer molecules into the pores caused a decrease in porosity and an increase in layer thickness at higher polymer concentrations. PMMA and PVC, two of the studied polymers, showed reduced 'n' and 'ε' values that were in close agreement with the experimental results.

REFERENCES

1. Nader.NandHashim.M.R.J.Electrochem.Sci.,7(2012)11513–11518.
2. Torres-Costa.VandMartin-Palma,R.J.J.Mater.Sci.,45(2010)2823–2838.
3. Doghmane.A,Hadjoub.Z,Doghmane.MandHadjoub,F.QuantumElectronOptoelectron.9 (2006)4–11.
4. DaFonseca.R.J,Saurel,J.M,Foucaran.S,camassel.J,Massone.E,taliercio.T,andBomaiza.Y.J.Mater.Sci.,30(1995)35–39.
5. Gupta,V.P,andRavindra,N.M.Phys.StatusSolidiB,100(1980)715–719.
6. Reddy,R.R,Anjaneyulu.S,andSamara.C.L.N.J.Phys.Chem.Solids.54(1993)635–637
7. Ravindra.N.M.andSrivastava.V.K.Phys.StatusSolidiB,93(1979)155–160.
8. Kumar.V,andSingh.J.K,IndianJ.PureAppl.Phys.,48(2010)571–574.
9. A.M.Sherry,M.Kumar.J.Phys.Chem.Solids.52(1991)1145.
10. J.L.Tall.Phys.Chem.Solids.41(1980)837.11. M.Kumar.PhysicaB.205(1995)175.
12. M.Kumar,S.P.Upadhyaya.Phys.Stat.Sol.(b).181(1994)55.
13. J.C.Phillips,BondsandBandsinSemiconductors,AcademicPress.SanDiego,1973.
14. W.A.Harison,ElectronicStructureandthePropertiesofSolids,GeneralPublishingCompany,Toronto,1973.
15. R.K.Pandey.J.Phys.Chem.Solids.59(1998)1157.
16. DaFonseca,R.J.M.,Saurel,J.M.,Foucaran,S.,Camassel,J.,Massone,E.,Taliercio,T.,andBoumaiza,Y.,J.Mater.Sci.,30 (1995)35–39.
17. N.M.Balzaretti,J.A.H.daJornada,SolidStateCommun.99(1996)943.
18. Ravindra.N.M,andSrivastava.V.K.InfraredPhys.19(1979)603–604.