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The effect of Incorporation Salt and graphite on the relative permittivity,refractive index and capacitance for porous silicon

تأثير تطعيم ملح الطعام والكرافيت على النفوذية النسبية،معامل الانكسار والسعة للسليكون المسامي

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ABSTRACT

In the present research some properties of porous silicon prepared by photo electro chemical etching process with different etching time (5,10,15)min, were studying dependence of these properties on the etching rate too. The relative permittivity, refractive index and capacitance for porous silicon were calculated were calculated for porous silicon exposure to ambient air, embedding with graphite, salt, respectively , and in the anther hand the search study theoretically, porous silicon and graphite, porous silicon and salt which made comparison for the results with matlab program assisted for mixing porous silicon and graphite and porous silicon and salt.

الخلاصة

في هذا البحث تمت دراسة بعض خواص السليكون المسامي حيث تم تحضير السليكون المسامي بواسطة عملية القشط الكهروضوئي-الكيميائي ولأزمان قشط مختلفة(5,10,15)دقيقة واعتمادية هذه الخواص على نسبة الحفر اثناء عملية القشط وتم حساب معامل الانكسار والنفوذية النسبية والسعة للسليكون المسامي حينما يكون ممتزج مع الهواء اي تكون فتحاته مملوءة بالهواء ومقارنة النتائج حينما تكون نظريا مملوءة بالكرافيت وملح الطعام اي السليكون المسامي عند الهواء والسليكون المسامي مع الكرافيت والسليكون المسامي مع ملح الطعام بالاستعانة ببرنامج الماتلاب للحصول على النتائج فقط عند خلط السيلسكون المسامي مع الكرافيت وعند خلط السليكون المسامي مع ملح الطعام لتوليد خواص مختلفة للسليكون المسامي.

Introduction

Porous silicon is a network from mixture between a void and very slim walls of Nanocrystallites, the void of this porous silicon full of with air, the surface of porous silicon like a brittle spongy structure [1], nanostructure of silicon is based on popular application between scientists specially after classified this a new matter as(micro porous(pore width$\leq 20nm$),meso porous(pore width$20-500nm$)or macro porous(pore width$>500nm$) according to the etching conditions[2],[3]; Porous silicon had different relative permittivity compared with bulk silicon and this causes various properties in capacitance and photovoltaic characteristics[2].

The electrical properties of porous silicon connected to the band gap which affect by confinement effects because band gap of porous silicon increases with comparison to the bulk silicon and make porous silicon have abased for many physical applications [4],the researchers cannot control the structure of porous silicon during prepare it but we can discover the behavior by using scientific methods and built some application according to this behavior.

Experimental Parts:-

In this research commercial crystalline silicon wafer and one side like mirror n-type (111) and resistivity ($\rho = 1.5-4\Omega.cm$) with thickness(508±15μm) using to make samples, This wafer was cut off in to small pieces and make a small circle interact with acid by radius (0.6cm) ,(1:10) HF:ethanol were clean the small pieces, Photo-electro-chemical etching process with(48%)concentration of HF, Figure(1) shows the setup of systematic with assisted 100W of Tungsten lamp was illuminate the small circle of the samples near(1.1309cm^2) to prepare nano

structure of silicon by mixing (1:1) HF:ethanol at room temperature and(Pt)electrod as a cathode with different etching time (5,10,15) min.

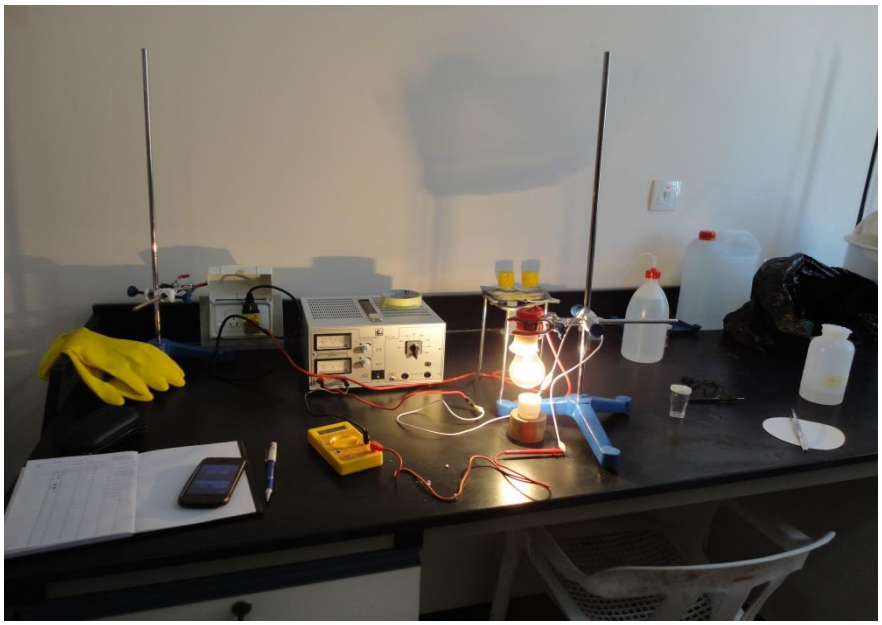

Figure 1: The setup of Photo-electro-chemical etching process to make porous silicon from bulk silicon.

By using gravimetric method, porosity and layer thickness were calculated by[5]:-

$$\%Porosity = \frac{m_1 - m_2}{m_1 - m_3}\% \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$layer\ thickness = \frac{m_1 - m_3}{\rho A} \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where m_1, m_2 are the weights of silicon samples before and after etching process respectively, m_3 is the weight after removed porous silicon layer, ρ the density of silicon, A the interaction area of bulk silicon with acid in systematic, etching rate can be determined by using the relation[6]:-

$$r_{etch} = \frac{d_{etch}}{t_{etch}} \dots\dots\dots\dots\dots (3)$$

Where r_{etch}etching is rate, d_{etch} the layer thickness of porous silicon, and t_{etch} represents the etching time.

The theoretical part:-

Bulk silicon had a relative permittivity $\varepsilon_{Si} = 12$, after photo electro chemical etching process the relative permittivity of porous silicon were not fixed because of the this relative permittivity mixing between air and silicon then the formula of Bruggeman can make the expression[5]

$$\mathrm{P}\frac{\varepsilon_{\mathrm{Si}} - \varepsilon_{\mathrm{psi}}}{\varepsilon_{\mathrm{Si}} + 2\varepsilon_{\mathrm{psi}}} + (1 - \mathrm{P})\frac{\varepsilon_{air} - \varepsilon_{\mathrm{psi}}}{\varepsilon_{\mathrm{air}} + 2\varepsilon_{\mathrm{psi}}} = 0 \dots\dots\dots\dots\dots\dots (4)$$

Where P is the porosity, $\varepsilon_{\mathrm{Si}}$ the relative permittivity of silicon, $\varepsilon_{\mathrm{psi}}$ the relative permittivity of porous silicon, ε_{air} the relative permittivity for a void (air),with some approximation, By develop the parallel model and serial model can get[7]:-

$$\varepsilon_{\text{psi}} = \text{P}\varepsilon_{air} + (1 - \text{P})\varepsilon_{\text{Si}} \dots\dots\dots\dots\dots\dots (5)$$

From the relative permittivity can be calculated the refractive index of the porous silicon can be calculated [8]:-

$$n_{psi} = (\varepsilon_{\text{psi}})^{\frac{1}{2}} \dots\dots\dots\dots\dots\dots\dots (6)$$

From dielectric constant one can find the capacitance for porous silicon [4]:-

$$C_{psi} = \frac{A * \varepsilon_{\text{psi}} * \varepsilon_{\text{o}}}{d_{etch}} \dots\dots\dots\dots\dots (7)$$

Where C_{psi} is the capacitance of porous silicon, ε_{o} is the permittivity for free space

The above equations deal with porous silicon and void fraction, in this paper two matters can be theoretical study, graphite incorporation-psi and Salt incorporation-psi and then comparison with pure psi, theoretically the air in the pore can be replaced by graphite or salt studying the change of the properties for the porous silicon.

RESULTS AND DISSCUSSION:

Many parameters effect on the porous silicon properties according to the preparation conditions of porous silicon and this make difference applications or this bases to many devices like solar cells, detectors, diodes, super doubles structure, gas sensors….etc[9],[10],[11].

Figure (2) shows the relation between the etching rate and the etching time at etching process, this sketch according equation(3), one can see the increasing in the beginning of the etching rate that is the increasing in etching time will lead to increasing rate of interaction between the acid and bulk silicon at the interface which exhausted the charge carriers in the bulk silicon and then reduce the behavior due to decreasing the interaction and make reduction etching rate because removing the porous silicon layer and make a new structure this result correspondence with many researches [12],[13].

From the mechanism of the formation nanostructure one can imagine the properties of porous silicon, figure(3) shows one of this properties that the relative permittivity as a function of etching time without any dopant by using equation(5) i.e porous silicon and air,[14] this figure resulted from the interaction between the relative permittivity of bulk silicon and the relative permittivity of the air before etching process, the value of the relative permittivity of bulk silicon only after etching process the air pore inside the porous silicon which make the reduction of permittivity for bulk silicon, the figure show lightly arising at etching time 10min because of after 5min the porous silicon layer was removed and beginning make a new structure but with lower porosity than 5min and with same reduction with a new matter[14],[15].

Figure(4),and(5) show the relative permittivity of porous silicon and etching time which calculated by equation(5),with replace the relative permittivity for air by the relative permittivity for(salt)and (graphite), then one can imagine pores of air in porous silicon full of by these matters and make anew characteristics which can be noted by figures(4) and (5),since the result of relative permittivity for porous silicon embedding between nanostructure of silicon with salt for figure (4), and embedding between nanostructure of silicon with graphite for figure(5),the behavior in figure (4) is same that in figure (3) but in higher value because of the relative permittivity of the salt is(10) then this value is bigger than air value and less than silicon value, in the other side the arising in the relative permittivity with respect to the etching time as shown in figure(5), this various may be coming from the relative permittivity of the pore(Graphite) is (12), this value is bigger than porous silicon value, from that one can find to change the properties of porous silicon by adding the impurities for the structure for the bases to any applications like gas sensor, solar cell[16],[17]

By using equation (6), the refractive index of porous silicon is proportionality with relative permittivity. Then refractive index make same behavior of relative permittivity as shown in figure

(6) which show the refractive index as a function of etching time, This figure show the reduction of the refractive index of porous silicon which made from the refractive index of bulk silicon pores of air and this direct effect to various electrical properties [12].

The effective of replace the air by salt and graphite on the refractive index for porous silicon can be showed in the figures (7) and (8).It represent the ratio between the velocity of the light in the vacuum with the velocity in the matter. The refractive index different from the matter to another depending on the composition and distance spaces for the material figure (7) and (8) coming from equation(6),this figures shows the behavior between the refractive index and the etching time which noted the fluctuation for the refractive index because the embedding between nanostructure of silicon and salt figure (7), nanostructure of silicon and graphite figure(8), one can see the reduction of the refractive index with respect to the etching time due to the rate of the salt in the figure (7),and the reason of the slightly increasing in the refractive index in the figure (8) with respect to etching time because of rate of the graphite which different with salt which change the refractive index for the new matter[18].

from the relation (7) can be calculated the capacitance as a function of etching time in the air as shown in figure (9), from this figure it can be concluded that the capacitance of porous silicon direct depend on the interaction between bulk silicon and acid at interface under our condition which need it, When the etching time increase, increase the capacitance of porous silicon because of the increase the rate of air in the pores of porous silicon which described as isolated dielectric between plates of capacitance and change the potential break down at the plates[19].

Table (1):-the capacitance of porous silicon with salt and graphite for different etching time

Etching time(min)	Capacitance of porous silicon(F) with(salt)	Capacitance of porous silicon(F) with(graphite)
0	∞	∞
5	$4.689272713*10^{-10}$	$5.549841744*10^{-10}$
10	$9.51306902*10^{-10}$	$1.092193175*10^{-9}$
15	$2.613628072*10^{-10}$	$3.081630829*10^{-10}$

the effect of the adding the graphite and the salt on the capacitance of porous silicon can be putting on the table(1).

The reduction of the capacitance can be shown by table (1), this reduction due to salt and the graphite which described conductors with comparison by air and make lower voltage break down then cannot keep the charges longer time than air[20],one can see the infinity sign in the above table because at etching time (0)minute there is no interaction between acid and silicon to make porous silicon, then there is no nano structure silicon layer thickness.

Conclusion:-

From the results, all the properties of porous silicon coming from the mechanism of the formation of porous silicon and the conditions of preparation of nanostructure of silicon which direct effect on the relative permittivity and the refractive index for a new matter, the fluctuation can be shown for the properties of porous silicon when adding salt and graphite because the mixture between nanostructure of silicon and a new matters with different characteristics, from that one can conclude optimized characteristics with porous silicon and make the based for different applications, from this result can be conclude a new capacitance between mixture more than one matters. and make anew contact for different materials and we can see the improved in the properties in porous silicon by embedding graphite more than pure air or embedding salt.

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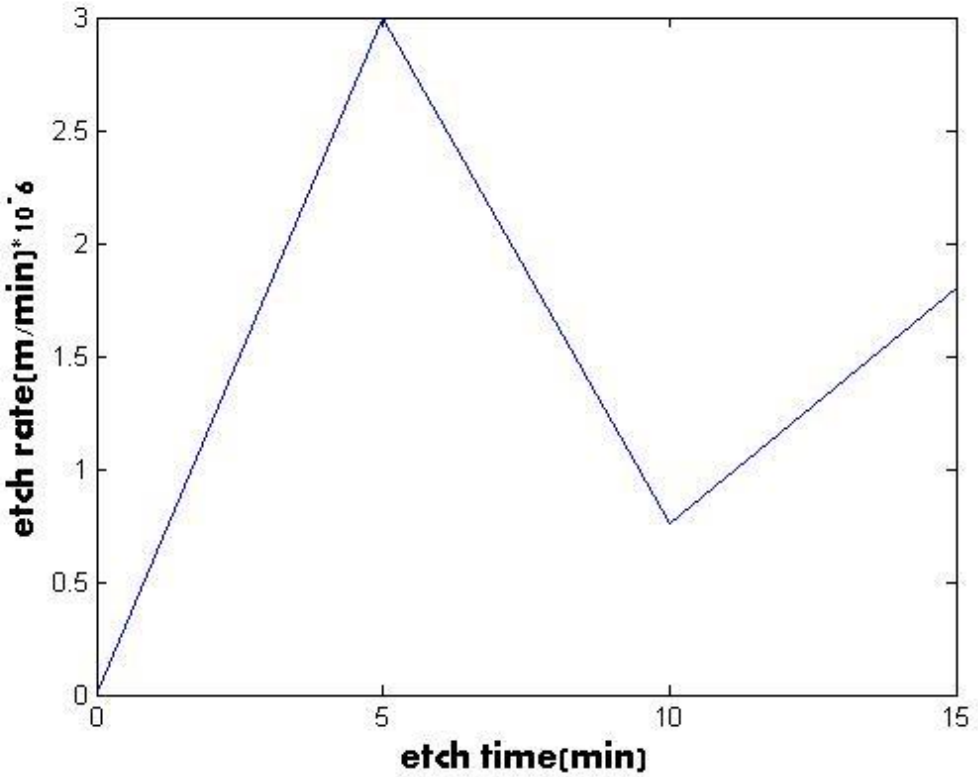

Figure (2):-The relation between the etching rate and the etching time for porous silicon

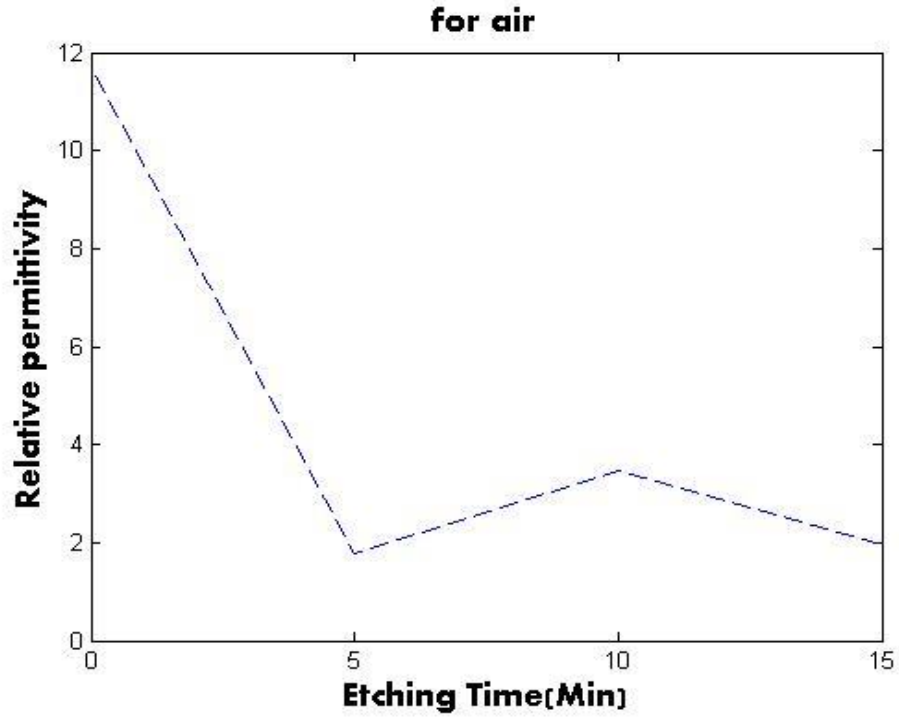

Figure (3):-The relation between Relative permittivity for porous silicon and etching time with air

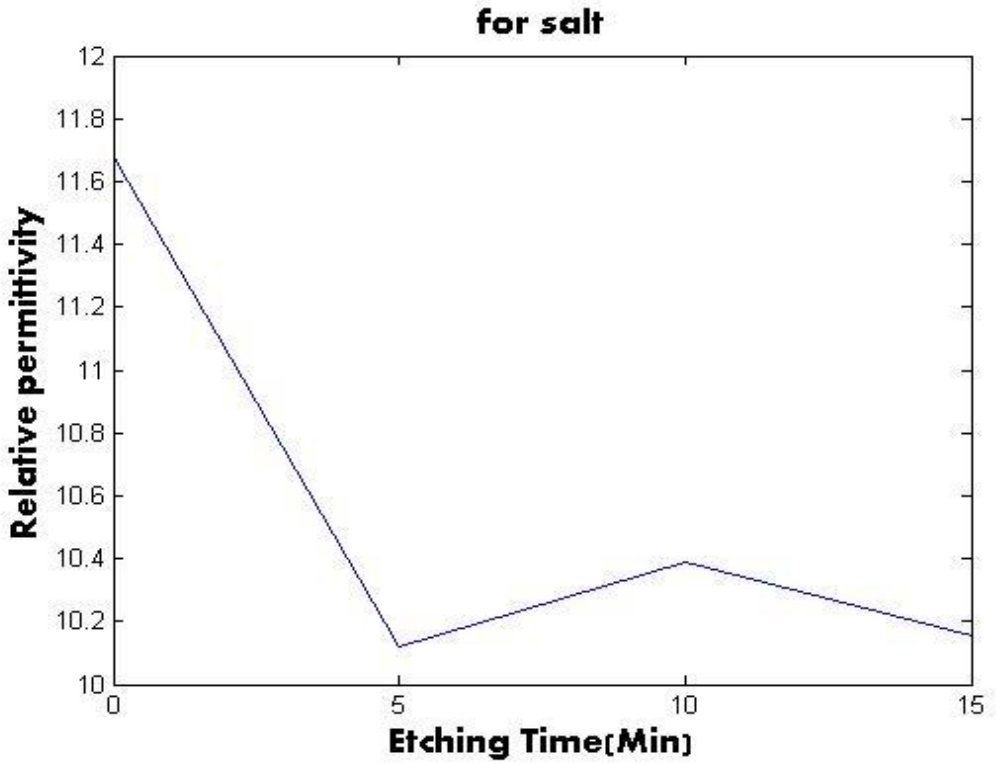

Figure (4):-The relative Permittivity for porous silicon as a function of etching time with salt

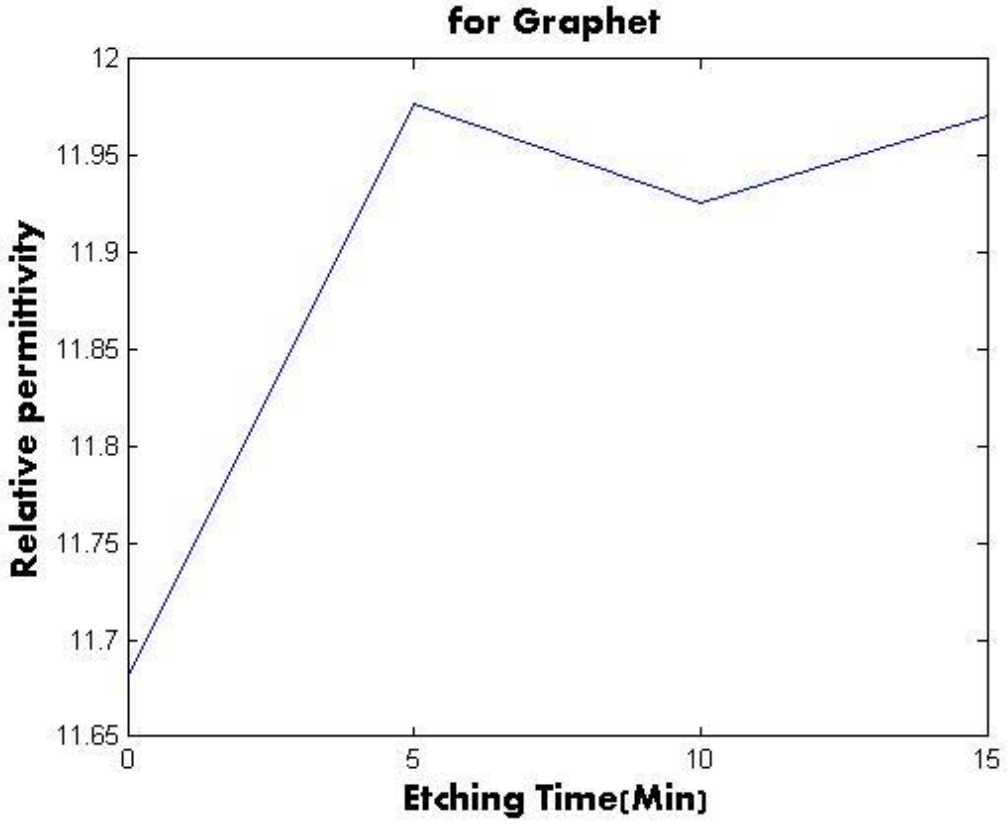

Figure (5):-The relative Permittivity for porous silicon as a function of etching time with Graphite

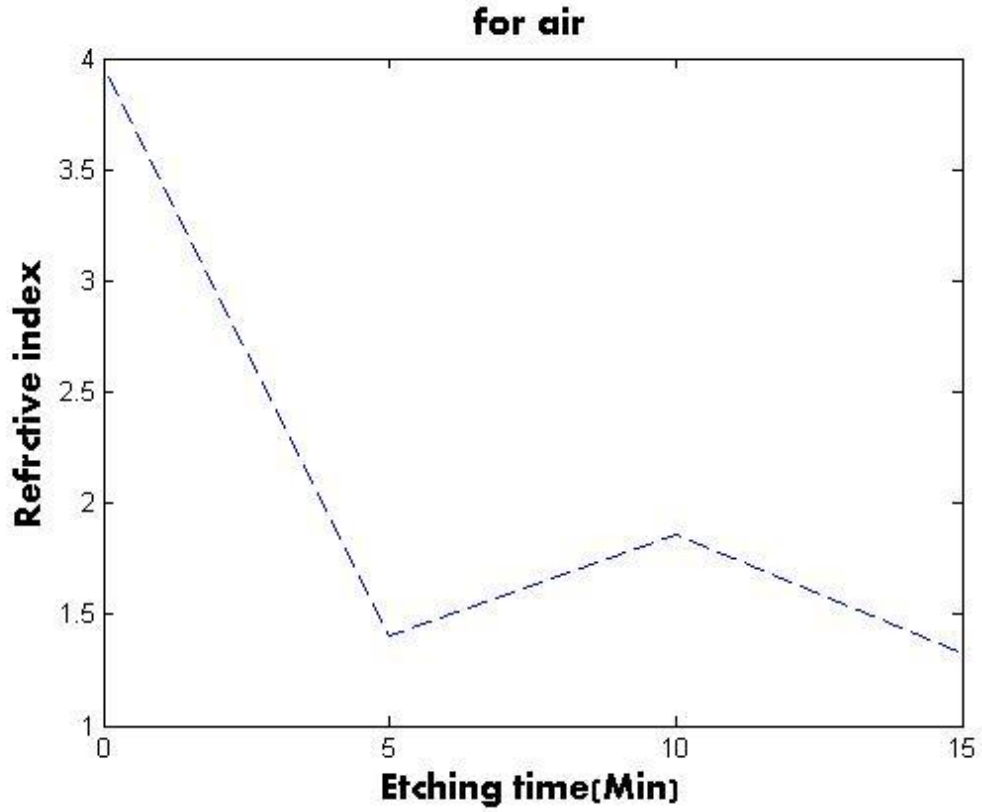

Figure (6):-The relation between Refractive index of porous silicon and etching time with air

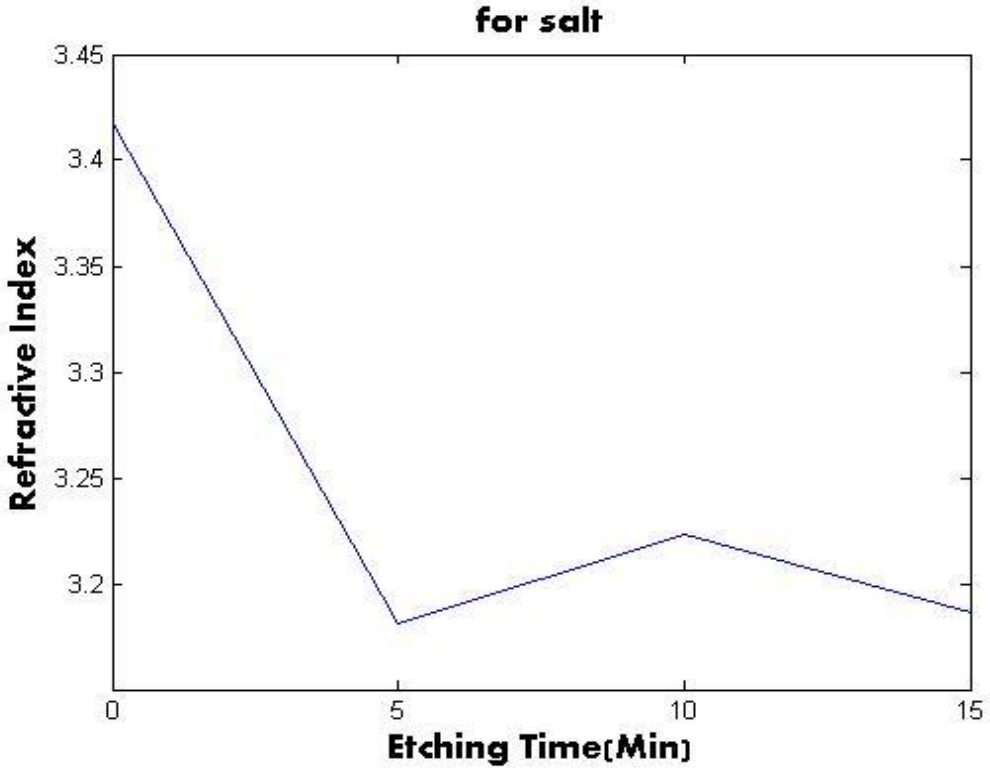

Figure (7):-The relation between Refractive index of porous silicon and etching time with salt

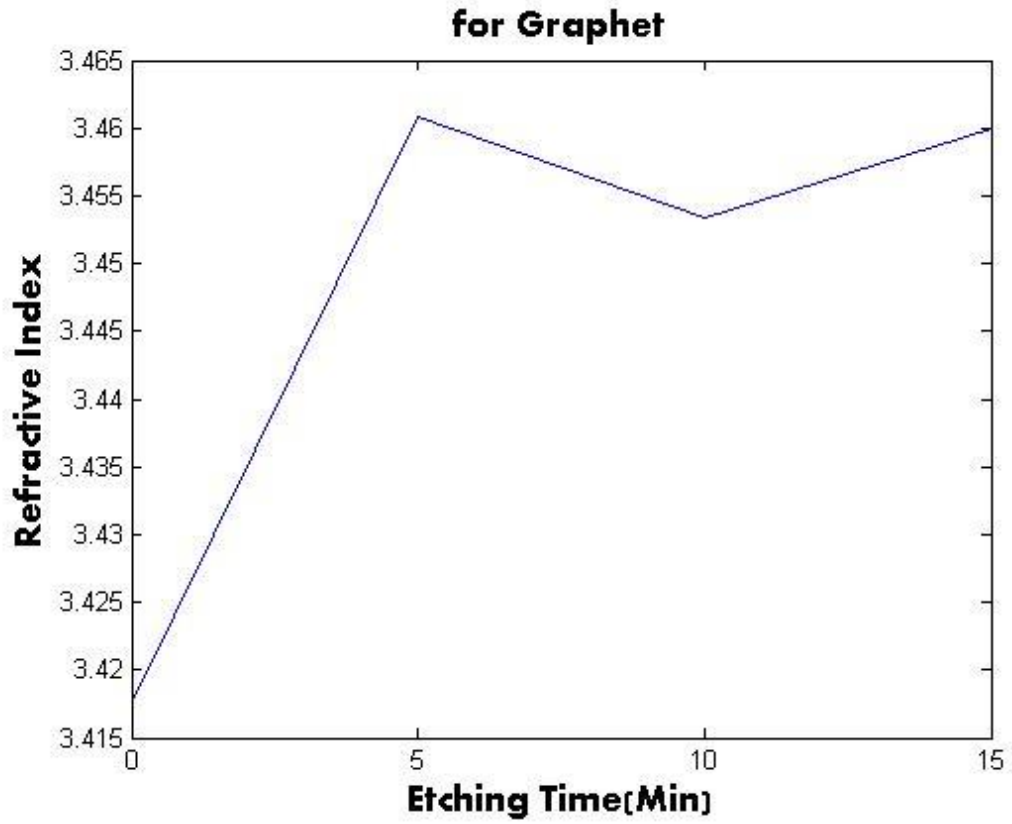

Figure (8):-The relation between Refractive index of porous silicon and etching time with Graphite

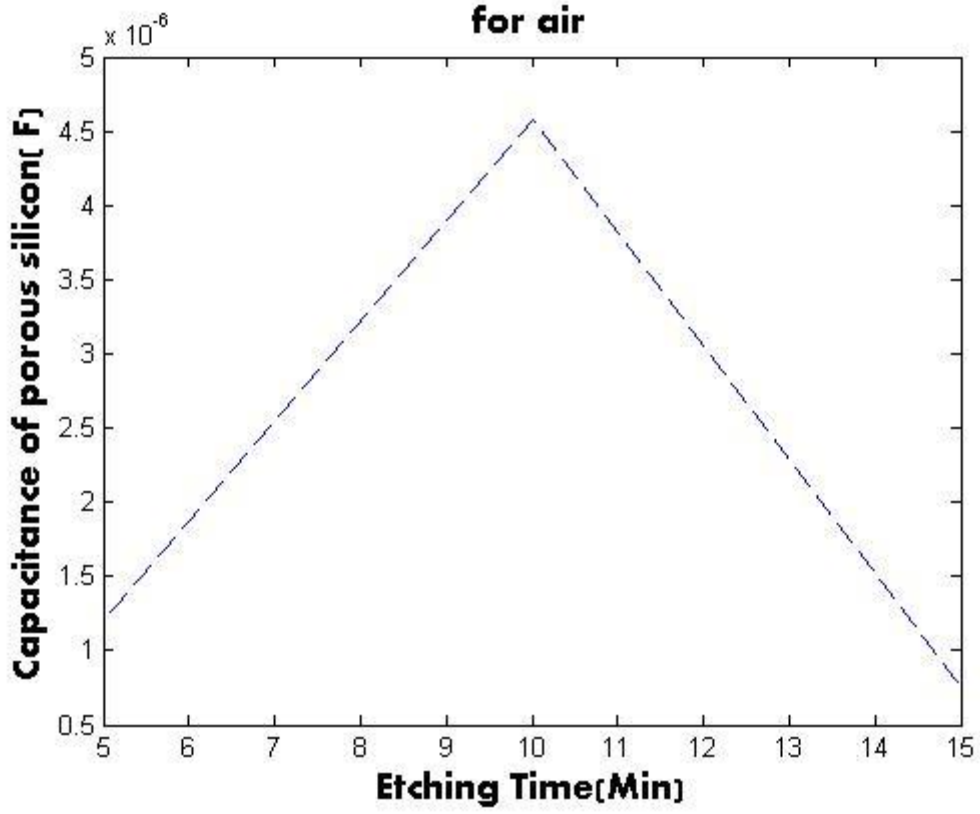

Figure (9):-The relation between capacitance of porous silicon and etching time with air