



Department of Electronics & Communication Engineering

GOVERNMENT POLYTECHNIC FOR GIRLS, SURAT

APRIL -2021: Vol.-1

EC TRENDS

E-Newsletter



Electronics & Communication Engineering

Vision:

Be an excellent department for girls to empower them in the field of Electronics and Communication engineering to excel in industry and serve society.

Mission:

- To prepare professionally competent students and staff through academic excellence.
- To create a conducive environment in the department for exchange of ideas and knowledge.
- To provide opportunities in the department for skill development and innovation.
- To provide resources and infrastructure for best learning experience in the department.

Message from Head of Department



DR. S. N. SAMPAT

HEAD OF DEPARTMENT (HOD) ELECTRONICS
AND COMMUNICATION ENGINEERING.

(I/C PRINCIPAL ,GPG . SURAT)

Dear students,

In reaction to the COVID-19 Global Pandemic, GPG, SURAT was closed to normal activity from March 2020, and successfully moved to a Distance Learning model. This monumental task was accomplished to observe the expectations and guidelines that the Government places on us through the Minister of Education to ensure our ongoing safety.

. It's exciting to think that, despite all the things that went wrong, we got things done. Thank you so much for your encouragement and your willingness to accept when we couldn't do things the way we traditionally had.

We are also proud that some of our Senior Members are taking an active role in sharing information and making sense of this situation.

I would like to conclude by thanking all staff, students and parents for your support and encouragement throughout this semester and particularly thank you for your flexibility in responding so graciously to the changes we have had to make to ensure compliance.

Governmental guidance in response to the coronavirus pandemic is being regularly updated. Please follow the instructions from Government on self-isolation, social distancing. By doing so, you are not only protecting your own health and that of people you live with, but you are also playing your part in reducing the impact of the virus on vulnerable people and on the economy.

I am hopeful We continue to follow all COVID-related safety procedures to remain healthy and safely.

Kind Regards,

Principal of GPG, Surat

Mr. Shaileshkumar M. Gheewala. Lecturer, Department of Electronics and communication Engineering & have published a paper in *HBRP Publication manuscript-1*. Here we have taken this document so that all can be aware of Simulation and Fabrication of Macro Porous Silicon for highly chemicapacitive detection for Aqueous Solvent

SIMULATION AND FABRICATION OF MACRO POROUS SILICON FOR HIGHLY CHEMICAPACITIVE DETECTION FOR AQUEOUS SOLVENT



MR. SHAILESHKUMAR MAHENDRALAL GHEEWALA
LECTURER, DEPARTMENT OF ELECTRONICS AND
COMMUNICATION ENGINEERING

EMAIL: SHAILESHMGHEEWALA@GMAIL.COM

ABSTRACT- Porous structured silicon material is most suited for sensing applications. In this paper, the fabricated porous structure silicon chemicapacitive device for sensing different chemical aqueous solvents. The design of the Porous Structure Silicon simulating in the 2-Dimension Synopsys Sentaurus Technology Computer-Aided Design (TCAD) tool. In the silicon substrate, the porous structure was fabricated by laser etching using Pulse Fiber Laser. Field emission scanning electron microscopy shows the average pore diameter 55.22 μm and pore depth 98.90 μm . Two front sides silver contact electrodes on the porous structure silicon made by colloidal silver conductive paste. The fabricated chemicapacitive device tested for different chemical aqueous solvents. The sensing electrical parameter is measured by the LCR meter. The application of the porous structure silicon chemicapacitive demonstrates the different concentrations of the ethyl alcohol aqueous solvent, which is used in medial, food, beverages, and fuel application. The fabricated chemicapacitive device gives a stable performance for 35 days of standard ambient temperature and pressure. The limit of detection and sensitivity of the fabricated chemicapacitive device was 0.474 ppm and 0.26 nF/ppm, respectively. The chemicapacitive based porous structure silicon is suitable for economical sensing and monitoring chemical aqueous solvent used in agriculture, beverages, chemical, medical, and pharmaceutical industries.

I. INTRODUCTION:

The definition of a “Sensor is a device which measured the change in the physical properties (i.e. light/heat/chemicals/pressure/motion/humidity) and responds to it”. In modern days sensors and their emerging technologies are widely used in aviation, automobile, diamond industries, environment monitoring, medical diagnosis, food, manufacturing, marine, mines, security, and textile industries. Sensor works and technologies strongly depend upon the materials and sensing mechanism. Many researchers have used the PSS for the main sensing materials. The PSS is discovered by Uhir and details work done by L. Chanham [1]. The fabrication of Either chemicals or instruments do PSS in the silicon wafer. The entire fabrication of PSS is divided into three etching processes: 1) Electrochemical etching (ECE) process, 2) Inductive Coupled Plasma (ICP) etching process, 3) Reactive Ion etching (RIE) process and 4) Laser etching (LE) process [2]. These all four etching process have their merits and demerits. In the ECE process, the manufacturing cost

of the PSS is meager. Still, during the batch processing, it does not produce identical PSS, etching rates are slow, and environmentally hazardous chemicals are used to manufacture the PSS. In ICP and RIE etching process has low etching rates, the fabrication cost is high due to costly instruments and materials. In LE etching process has high accuracy, identical batch processing, non-contact processing, and speedy processing. Three types of lasers are used for the fabrication of the PSS: 1) CO₂ laser ($\lambda=10.64\mu\text{m}$), 2) Nd:YAG laser ($\lambda=1.064\mu\text{m}$), and 3) PFL laser ($\lambda=1.064\mu\text{m}$). Compare these three lasers co₂ laser wavelength not absorbed by the silicon wafer for that extra Pyrex glass materials put below the silicon wafer [3]. In CO₂ and Nd:YAG lasers required high chiller power, and their instrument maintenance cost higher. PFL laser instruments required less operating power, the fabrication cost is low [2]. Also, we discuss that pore diameter and depth can be controlled by controlling the parameters like laser power, pass numbers, and scanning speed.

The main properties of PSS have larges surface to volume ratio, skeleton type spongy surface material, variables pore and depth sizes, controllable structural modification, and relevance with present silicon technologies. The PSS electrical and optical properties will change due to material inside the pore which makes the suitable application for sensing like Bragg mirror, Fabry–Perot films, multi-cavity for gas detection, humidity, organic solvent, pathologies, virus, and bacteria detection, pesticides detection, solar Cell, micro-electromechanical system [2, 4-13]. The main merits of photonic the sensing mechanism of PSS are fast response, safer to use in hazardous environment while main demerits are low device sensitivity, and cost of instruments are high whereas in electrical sensing mechanism required lower cost operation, sensitivities are good and easy device handling capabilities.

Electrical sensing mechanism can be done by using resistive, inductive, and capacitive principles. In the resistive sensing mechanism, the main demerits are lower sensitivity, high power consumption, and always senses a single point of contact. In the inductive sensing mechanism, the main demerits are detected only metallic target only and design and fabrication is coil size which is very difficult to design in Integrated circuit. A capacitive sensing mechanism is a simple construction, lower cost, high sensitivity used for detecting the non-metallic target, and operated at the low power supply.

In the capacitive sensor for the aqueous solution sensing, wherein the change in the aqueous solution between the two contacts a change in the dielectric material. This causes variation in capacitance. The change in the capacitance is given by:

$$C = \epsilon_r \left(\frac{A}{d} \right) \quad (1)$$

Where C = Capacitance,
A- is the area of the structure, d - is the distance between the electrodes,
 $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$, and
 ϵ_r is the relative permittivity of the Aqueous Solvent.

From equation 1, C is a function of

$$C = f(\epsilon_r, A, d) \quad (2)$$

By changing any one value and the other two parameters are constant, the value of C will change. This is shown in Fig. 1.

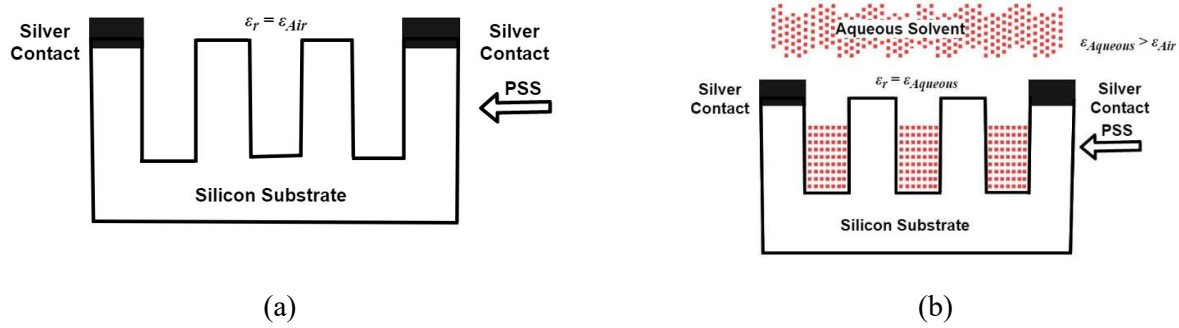


Figure 1 Schematic cross-section of the PSS capacitive sensor and its dielectric permittivity changes in the presence of (a) Air, (b) Aqueous Solvent.

Here we change the permittivity of the PSS and from the equation 1 and 2, the value of the PSS capacitance will be change.

In the market, most of the available commercial capacitive sensors are working on metal oxide sensing principles. Metal oxide sensors have to be operated on selective gas at a specific range of temperatures. At the same time, the PSS sensor works in ambient conditions. The metal oxide sensor is not compatible with silicon technologies, while the PSS is compatible with silicon technologies. The above discussion shows that the PSS is the best material for sensor application [7].

The objective of this paper is simulation to fabricate and characterize the PSS chemicapacitive sensor device application. In section 2, the PSS simulation was done in using the Synopsys Sentaurus 2-D TCAD tool to characterize it. While in section 3, fabrication of the PSS, characterization, and sensing methodology are presented, and, simulation and experimental results are compared in section 4.

II. SIMULATION OF THE PSS

The PSS is a composite material of air and silicon pillar array. It is a spongy-type skeleton structure to make an identical material for an electrical sensor device. The PSS design and simulation developed in Synopsys Sentaurus 2-D Technology Computer-Aided Design (TCAD) tool [14]. As described in our earlier publication this design of the PSS in the 2-D TCAD finalized [2]. A silicon substrate <100> was doped with the p-type born impurity with 10^{18} cm^{-3} concentration. For the simulation process, $275 \text{ } \mu\text{m}$ thick and $1 \text{ } \mu\text{m}$ long, and substrate resistivity $0.01\text{-}0.02 \text{ } \Omega\text{-cm}$ was designing. Fig. 2 shows the design of the PSS in the 2D-TCAD tool. The PSS is a process in-process tool and characterization in the device-tool module under 2-D TCAD simulation. The design specification of the PSS is shown in table 1.

Table 1 Design specification of the PSS

Sr. No.	Specification	Value
1	Pore depth	$98.9 \text{ } \mu\text{m}$
2	Pore width	$55.22 \text{ } \mu\text{m}$
3	Pore Separation	$22 \text{ } \mu\text{m}$

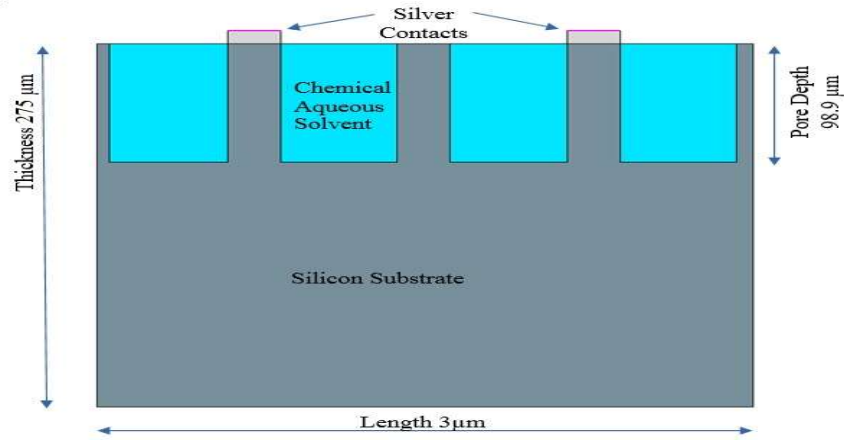


Figure 2 Cross Section of the implemented PSS in 2-D TCAD.

To account for the carrier transport phenomenon, the doping sensitivity mobility model was used. Shockley-Read-Hall physics has been used to capture many other phenomena in charge carriers, like generations and recombination [1, 15-16]. Silver (Ag) metal is used as a contact electrode for the PSS capacitive sensor device. The doping level of the boron is high in the substrate. As a result, capacitors and resistors in the model of the PSS are ideal.

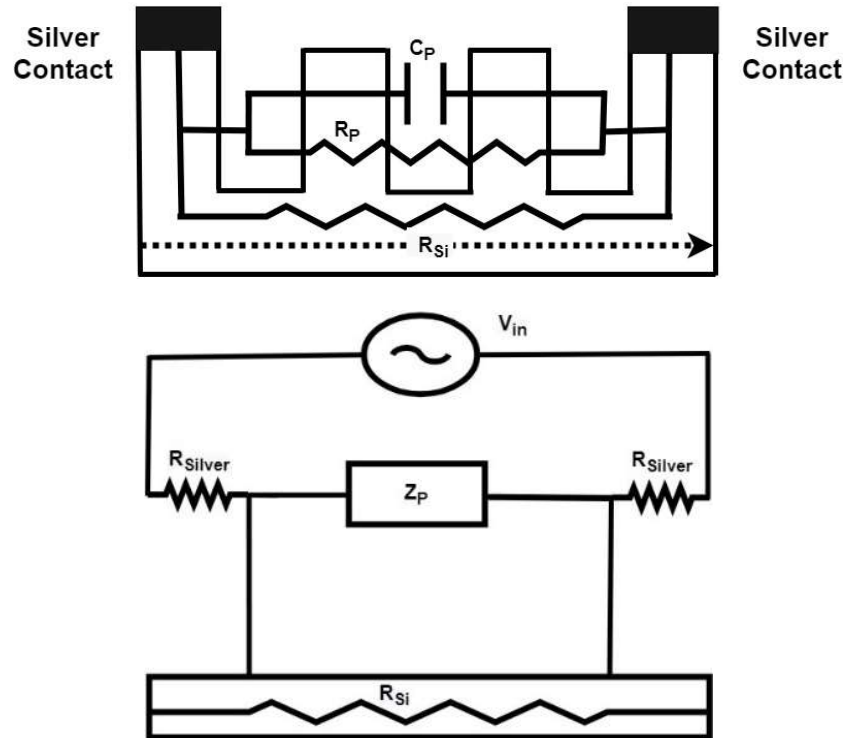


Figure 3 (a) Schematic model of the PSS have C_p , R_p , R_{Silver} , and $R_{Silicon}$ of the substrate, (b) Equivalent circuit of the PSS model.

The schematic model of the PSS and its equivalent circuit is shown in Fig. 3. Different passive components are present in the model at various points. These components are C_p , R_p , R_{Si} , and R_{Silver} . From Fig. 2 (b) Z_p is the porous junction, C_p is the pore capacitance and R_p is the pore resistance, i.e. $Z_p = C_p \parallel R_p$. R_{Silver} is the silver metal electrode resistance, and R_{Si} is the resistance of the silicon subtract. The equivalent impedance of the PSS model is

$$Z_{equivalent} = 2 R_{Silver} + (Z_p \parallel R_{Si}) \quad (3)$$

From the Fig. 1 (b) and Equation 1, 2, and 3, it should be noted that the value of CP is a function of the dielectric constant of the aqueous solution inside the pore. Here the value of the subtract resistance R_{Si} is created negligible effects on the sensing mechanism because R_{Si} depends on the concentration of the boron is 10^{18} cm^{-3} [15-16]. So sensor output impedance value depends upon the dielectric constant of the aqueous solution inside the pore. The aqueous solution like dimethyl ketone, ethyl alcohol and methyl alcohol dielectric constant values applied to the PSS model with 100 kHz frequency, and 100 mV input voltage was applied for simulating the sensor devise. The simulated results of aqueous solvents dielectric constant are illustrated in Table 3. Electric field distribution outline of 2-D TCAD model shown in Fig. 4. for different aqueous solutions like dimethyl ketone, ethyl alcohol, and methyl alcohol inside the PSS pore.

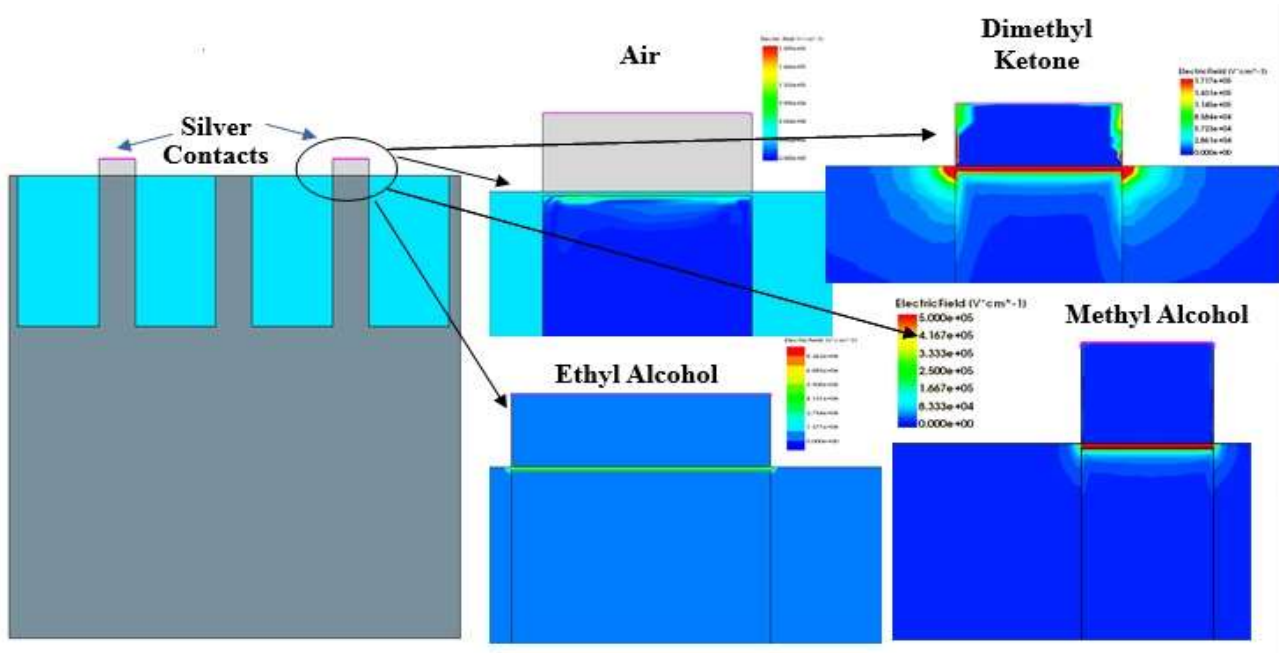


Figure 4 Outline of electric field distribution of air, dimethyl ketone, ethyl alcohol and methyl alcohol inside the PSS pore.

III. Experimental implementaion of PSS.

A. Materials

The PSS was fabricated using single side polished p-type boron-doped silicon wafer with orientation $\langle 100 \rangle$, resistivity $0.01\text{-}0.02 \text{ } \Omega\text{-cm}$, and $275 \text{ } \mu\text{m}$ thick. Sulphuric acid (H_2SO_4) 98 wt. % and Hydrogen peroxide (H_2O_2) 38 wt. %, Dimethyl ketone ($\text{C}_3\text{H}_6\text{O}$) 58.08%, ethyl alcohol ($\text{C}_2\text{H}_6\text{O}$) 46.07%, and methyl alcohol (CH_4O) 32.04% of these solutions were brought from Rankem-India Limited. Silver (Ag) colloidal, the conductive paste was purchased from Sigma-Aldrich, India.

B. Fabrication Method of Porous Si-Chip

The boron-doped P-type Silicon wafer cleaning with standard piranha cleaning method [2, 4-7]. With the help of the PFL etching mechanism first silicon wafer cut into the dimension, $1.5 \times 1.5 \text{ cm}^2$, and the PSS structure was created with a total of 7922 pores in the area of 0.785 cm^2 . The schematic diagram of the PFL setup is shown in Fig. 5.

The technical experimental setup specification PFL laser machine is shown in Table 2. And schematic diagram of an experimental process flow for making the PSS, using PFL shown in Fig.6;

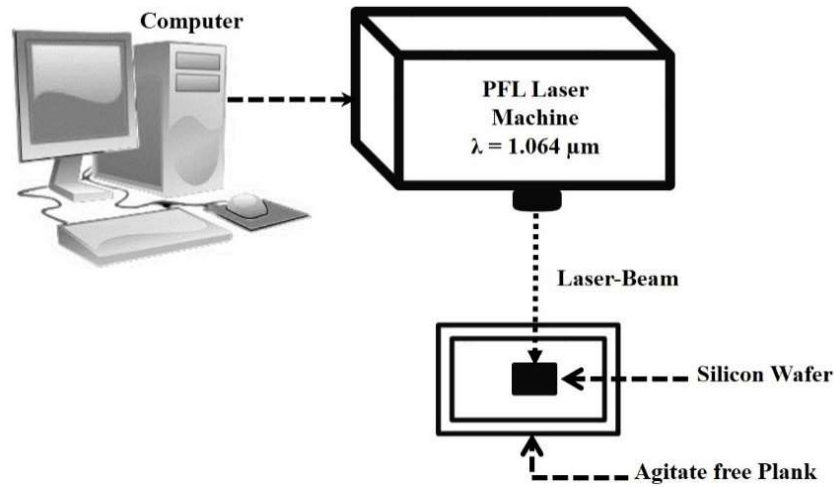
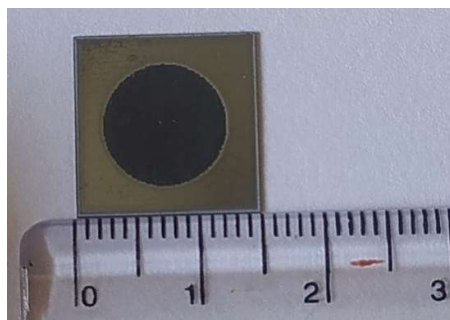


Figure 5 The schematic diagram Experimental setup for making the PSS using PFL.

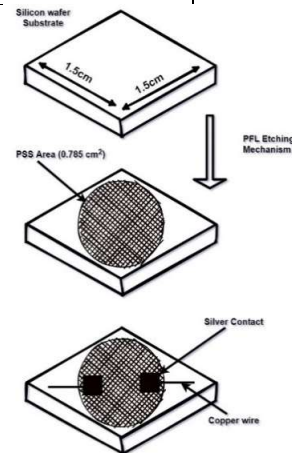
The technical experimental setup specification PFL laser machine is shown in Table 2. And schematic diagram of an experimental process flow for making the PSS, using PFL shown in Fig.6;

Table 2 Technical experimental setup Specification of PFL laser Machine.

Sr. No.	Parameter	Value
1	Wavelength (λ)	1.064 μm
2	Resolution frequency (f)	20,000 Hz
3	Loop Count	1
4	Speed	5 cm/Sec
5	Output Power (P)	27 watt
6	Mode of operation	Pulsed Mode



(a)



(b)

Figure 6 (a) Schematic cross section view (b) experimental process flow for the making the PSS.

A thin layer of oxide is required for the device's proper operation. The next step to grow the oxide on the PSS. Electrochemical oxidation applied for growing a thin oxide on PSS is the best technique. Because high-temperature oxidation grows stress in the PS, while low-temperature techniques like Chemical Vapor Deposition (CVD) cannot grow the oxide on the PSS pillar. But electrochemical oxidation occurs at SATP condition with Hydrogen peroxide (H_2O_2). For that, the PSS sample was immersed for two days at SATP. The thin layer of oxide makes the PSS water-insoluble and allows the infiltration of aqueous solvents into the pores.

Figure 6 (b) shows the process flow of the making procedure of the PSS capacitive sensor device. Two front side Silver (Ag) contact made using Silver (Ag) colloidal, the conductive paste. Two Cu wires bond with the Silver pasted backing in the muffle furnace [4-7], at 100 °C for 100 minutes shown in Fig. 7.



Figure 7 MUFFLE FURNACE.

C. The PSS Characaterization

After LE, a micro-sized pore creates in the Silicon wafer. These are examined for structural morphology into the Field-Emission Scanning Electron Microscopy (FE-SEM). The array of the dark and bright can be seen clearly in the top-view image. The dark side represents the void, and the bright side represents a matrix of the Silicon. The micro image in Fig. 8. of the PSS under FE-SEM shows that LE creates the uniform size of the pore with an average diameter of 55.22 μm and depth of 98.90 μm creates.

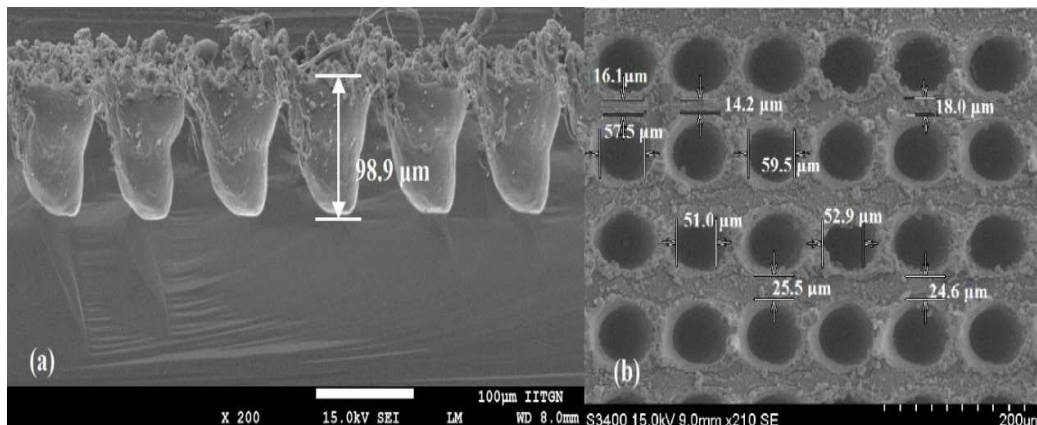


Figure 8 FE-SEM image of the PSS (a) Cross-sectional view (b) Top-view image.

The oxidized PSS, Structural crystalline materials have been done under Scintillator NaI (Ti)-XRD, as shown in Fig. 9. It shows the peak diffraction $2\theta = 68.32^\circ$, it corresponds to the Si (400) plane reflection from the bulk Silicon crystal orientation $\langle 100 \rangle$. This value is near reference to XRD data [17], indicating that the porous structure has been sufficiently oxidized.

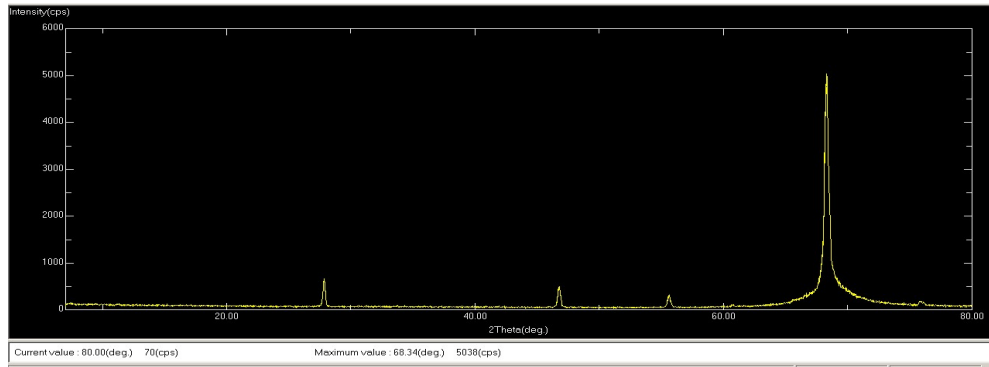


Figure 9 XRD spectra of oxidized porous Si-structure.

Experimental Setup of PSS chemicapacitive sensor

Fig. 10. shows the complete setup for capacitive measurement of the PSS capacitive sensor device using LCR meter, micro-Pipette, and Vibration free pad. Chemical aqueous solvent is inject in to the PSS capacitive device using micro-pipette.

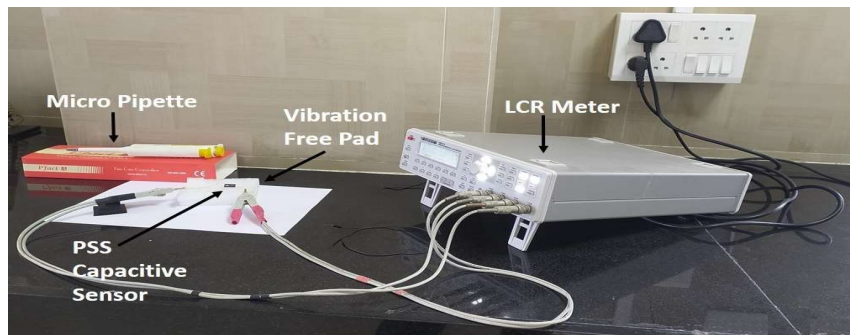


Figure 10 Image of the experimental setup for messurement of the air capacitor.

After the fabrication, characterization and experimental setup of the PSS capacitive device, the first step to standardize the device. For that, using the LCR meter, we applied the frequency range over 0.1 kHz to 100 kHz applied to the bare sensor with a 100 mV ac signal. Fig. 11.

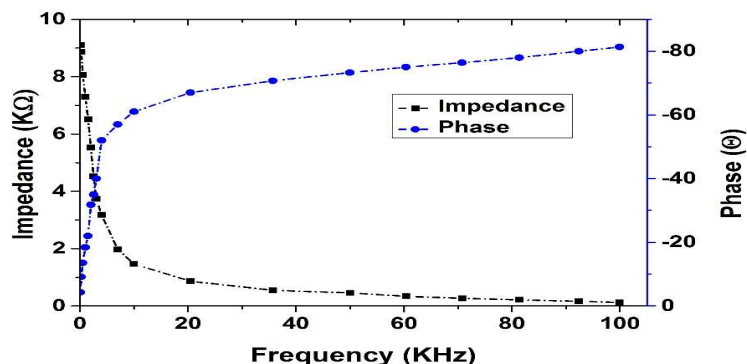


Figure 11 Impedance and Phase plot over the Frequency.

From the impedance and phase plot over the frequency shows that at higher frequency device effect is capacitive, while at low frequency, the device's impedance is high. So over experiment taken out at 100 kHz, 100 mV A.C. signal.

Results & Discussion

Before the testing start, the PSS sensor device surface dried using N_2 gas. In our experiment, each sample test was carried out at least five times to credibility the testing data. 10 μ L volume of the chemical aqueous solution like dimethyl ketone, ethyl alcohol, and methyl alcohol has different dielectric constant tests. The selection of the 10 μ L volume allows easy sample handling capacity and provides enough evaporation time for solvent.

From the equation 2 and 3, the value of the PSS sensor device for air is 0.23 fF/ μ m². And reaming chemical aqueous solution values for 2-D TCAD simulation tool and experimental values listed in table 3 and its value shown in Fig. 12.

Table 3 DETAILS OF SIMULATED AND MEASURED NORMALIZED CAPACITANCE OBTAINED FOR THREE DIFFERENT AQUEOUS SOLVENTS USING THE PSS CHEMICAPACITIVE SENSOR.

Sr. No.	Chemical Aqueous Solvent and its Dielectric constant	Simulated Normalized (C/Area) (fF/ μ m ²)	Experimental Normalized (C/Area) (fF/ μ m ²)
1	Air ($\epsilon = 1.0$)	0.33	0.23
2	Dimethyl Ketone ($\epsilon = 20.7$)	0.60	0.42
3	Ethyl Alcohol ($\epsilon = 24.5$)	0.67	0.46
4	Methyl Alcohol ($\epsilon = 33.6$)	0.80	0.58

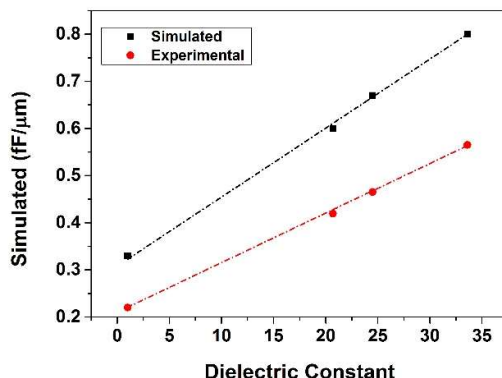


Figure 12 Comparison of simulated and measured normalized capacitance of the porous Si-chip for organic solvents with different dielectric constant value.

It is found that the PSS capacitive sensor device response for simulation and experimental values are linear. But a minor difference in the simulation and experimental values is observed. Because simulation design does not consider the shape of the pore depth, size, and roughness of the PSS. In practice, these parameters change the capacitor values.

A fabricated sensor was tested for the thirty-five days at SATP, and a difference was observed due to the aging of the sensor. Aging is the crucial parameter for the sensor due to native oxide grown onto the PSS surface in uncontrolled manners. Aging leads the incorrect output result.

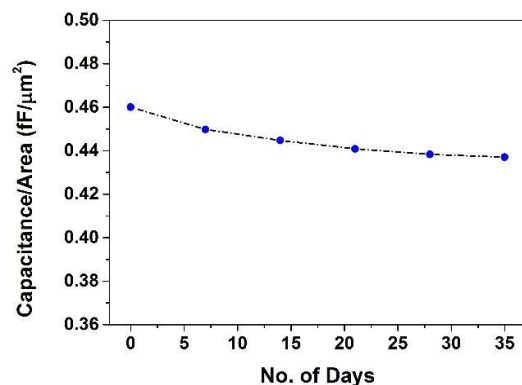


Figure 13 Aging effect in the sensor output with time in number of days for Ethyl Alcohol.

Another name of the aging in the sensor mechanism is known as drift analysis. The output result for Ethyl Alcohol shown in Fig. 13 found stable and negligible drift at sensor output.

Application of the PSS sensor analysis of Ethyl Alcohol Concentration.

Our fabricated PSS capacitive sensor has been applied to determine different ppm solutions of Ethyl Alcohol in the water. Ethyl Alcohol (C_2H_6O) is also known as a Grain Alcohol and having International Union of Pure and Applied Chemistry (IUPAC) name is Ethanol. It is a colorless, flammable, and little toxic organic aqueous solvent. In the researcher's society, its molecular formula is abbreviated as an EtOH. Ethyl Alcohol links to the hydroxyl group, and its hydroxyl bond is shown in Fig. 14.

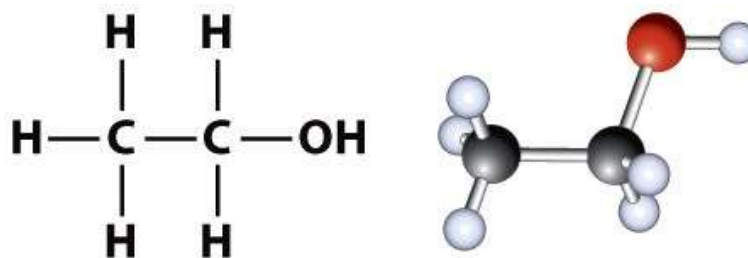


Figure 14 Ethyl Alcohol Hydroxy bond.

Ethyl Alcohol used in the medical application, food application, use as mixing with commercial gasoline A92 fuel in an American continental, and drinking as an Alcohol beverage.

The most useful of the Ethyl Alcohol in the current Covid-19 pandemic as Ethyl Alcohol based hand-sanitizer. With the help of Ethyl, Alcohol killed the bacteria and virus 99.9%. The Centers for Disease Control (CDC) and Prevention advises that people choose to buy the hand-sanitizer with contains more than 60% of Ethyl Alcohol. Less than contain 60% of Ethyl Alcohol not classified as a hand sanitizer.

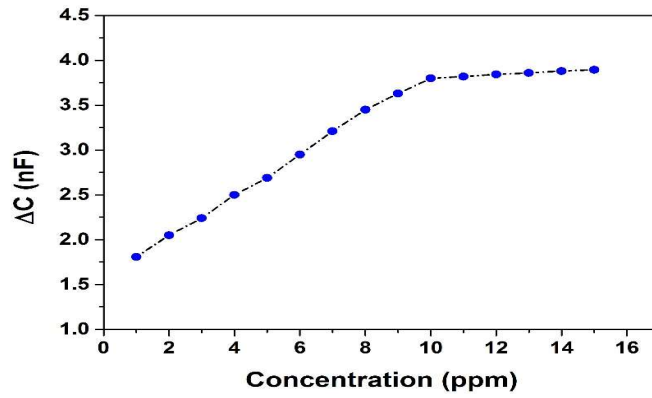


Figure 15 Plot of capacitance measured for different concentration of Ethyl Alcohol.

Fig. 15. shows the concentration of Ethyl Alcohol versus change in the capacitance value ΔC (nF). ΔC is the value of each concentration difference of Ethyl Alcohol and the capacitance's initial value of the capacitance, i.e., air value.

Table 4 Change in the Capacitance measured from the PSS chmicapacitive sensor different concentration of Ethyl Alcohol

Sr. No.	Concentration (ppm)	ΔC (nF)
1	1	1.806
2	2	2.049
3	3	2.239
4	4	2.499
5	5	2.689
6	6	2.949
7	7	3.209
8	8	3.449
9	9	3.629
10	10	3.799
11	11	3.819
12	12	3.843
13	13	3.860
14	14	3.880
15	15	3.893

It's important to note that the PSS sensor device response is linear up to 10 ppm Ethanol water concentration. Above 10 ppm it the response was non-linear due to saturation. To analyze the evolution of the PSS sensor device, sensitivity (S) is calculated as

$$S = \frac{\Delta C}{\Delta \text{Concentration}} \text{ nF/ppm} \quad (4)$$

Where S is sensitivity, ΔC denotes the change in the capacitance value, and $\Delta \text{Concentrations}$ indicates a change in the concentration level of the Ethyl Alcohol aqueous solution. The calculated sensitivity value of the PSS sensor device is 0.26 nF/ppm. Further, the limit of detection (LOD) was calculated as [7, 18],

$$LOD = K \times \left(\frac{SD}{S} \right) \quad (5)$$

Where SD is the standard deviation, S denotes the measured sensitivity, and $K = 3.3$ is a constant selected concerning 95% confidence level [7, 18]. From equation 5, calculated LOD value is 0.474 ppm.

Also, Fabricated the PSS sensor device used as a reversible sensor 0.474 ppm application. After each experiment, Ethyl Alcohol aqueous solvent was removed by rinsing the sensor device five times into the DI water. Then the device dried using Nitrogen gas; thus, device capacitance comes to its original values. The sensor comes back to the initial value is an important feature of the PSS capacitive sensor device.

Conclusions

In this work, the Porous Structure Silicon-based capacitive device where simulation in a 2-D Synopsys Sentaurus Technology Computer-Aided Design tool and fabricated using a laser-etching technique using Pulse Fiber Laser. 7922 pores are fabricated in the area of $0.785 \mu\text{m}^2$. From the experiment result following conclusions are drawn. The FE-SEM image of the structure confirmed the porous structure with an average pore diameter of $55.22 \mu\text{m}$ and depth of $98.90 \mu\text{m}$. The experiment of fabricated sensor devices with different chemical aqueous solvents having different constant shows the linear response. The fabricated sensor device also tests for 35 days at SATP, shows a stable response. The use of the fabricated sensor device for different concentration of Ethyl Alcohol, demonstrate the application of sensor device for sensing different aqueous chemical solvent in the industry. The proposed sensor device can use for suitable low-cost agriculture bio-sensing applications.

Acknowledgment

The authors thank the Technical Education Quality Improvement Program Phase-III (TEQIP-III), Sardar Vallabhbhai National Institute of Technology, Surat, for supporting this research work. They would also like to acknowledge the Sensor Research Laboratory, Sardar Vallabhbhai National Institute of Technology, Surat, for providing the research facility. This paper results from the R and D work attempted in the undertaking under the Visvesvaraya Ph.D. Scheme of Ministry of Electronics and Information Technology, Government of India, being executed by Digital India Corporation (once in the past Media Lab Asia). The authors are thankful to the Central Instrumentation Facility (CIF) at IIT Gandhinagar for helping in the structural characterization of the samples. The authors also thank Shri. Sagar Jagtap, Sophisticated Instrumentation Centre, Mechanical Engineering Department at Sardar Vallabhbhai National Institute of Technology, Surat, for the structural characterization of the samples.

References

- [1] L. T. Canham.: Properties of Porous Silicon. INSPEC, LONDON, 1st Edition, 1997.
- [2] Gheewala SM., Fabrication of Macro Porous Silicon Structures Using Pulsed Fiber Laser Technique for Capacitive Sensor Application. In: Gupta S., Sarvaiya J. (eds) Emerging Technology Trends in Electronics, Communication and Networking. ET2ECN 2020. Communications in Computer and Information Science, vol 1214. Springer, 2020.
- [3] C.K. Chung, M.Y. Wu, E. J. Hsiao and YC. Sung.: Etching Behaviour of Silicon Using CO₂ Laser. proceedings of 2nd IEEE International Conference of Nano/Micro Engineered and Molecular Systems, Bangkok, p.p. 59-62, 2006.
- [4] P. N. Patel, V. Mishra, A. K. Panchal, N. H. Maniya., Realization Of Porous Silicon Distributed Bragg Reflector For Optical Sensing Applications, Sensors & Transducers Journal (S & T), vol. 139 (4) pp. 79-86, 2012.
- [5] P. N. Patel, V. Mishra, A. K. Panchal, Nano porous silicon microcavity optical biosensor for glucose detection, Digest Journal of Nanomaterials and Biostructures Vol. 7(3), 973 – 982, 2012.
- [6] Vivekanand Mishra, P. N. Patel, Suchitra Kumari, Gourav Mishra, Dengue NS1 Detection used Chemically Modified Porous Silicon Microcavity (PSMC), Springer, Silicon, 2014.

- [7] S. M. Gheewala, Chinthakunta P, P. N. Patel, R. Dhavse, Development of Micro-Machined Porous-Silicon Capacitive Chip for Quantification & Sensing of Organic Solvents. *Journal of Solid State Technology* vol. 64 (2), 4725-4739, 2021.
- [8] María R. Jiménez-Vivanco, Godofredo García, Jesús Carrillo, Vivechana Agarwal, Tomás Díaz-Becerril, Rafael Doti, Jocelyn Faubert and J. E. Lugo, Porous Si-SiO₂ based UV Microcavities, *Nature research scientific report* 10, 2020.
- [9] Alwan, A.M., Hashim, D.A. & Jawad, M.F., CO₂ gas sensor based on macro porous silicon modified with trimetallic nanoparticles. *Journal of Materials Science: Materials in Electronics* volume 30, pages7301–7313, 2019.
- [10] Mahmood Bahar, Hamideh Eskandari and Naghi Shaban., Electrical Properties of Porous Silicon for N₂ Gas Sensor. *Journal of Theoretical & Computational Science*, 4 (1), 1-6, 2017.
- [11] Peishuai Song, Zhe Ma, Jing MaRecent, Progress of Miniature MEMS Pressure Sensors micromachines, MDPI, 2020.
- [12] A. A. S. Mohd Radzi, M. Rusop, and S. Abdullah, Optical Properties of Multilayer Porous Silicon with Different Fabrication Conditions for Application along Telecom Band, *IEEE International Conference on Semiconductor Electronics (ICSE)*, Kuala Lumpur, 184-187, 2018.
- [13] Bui, H., V. H. Pham, V. D. Pham, T. B. Pham, T. H. C. Hoang, T. C. Do, and T. V. Nguyen. "Development Of Nano-Porous Silicon Photonic Sensors For Pesticide Monitoring." *Digest Journal of Nanomaterials & Biostructures (DJNB)*, vol.13, no. 1, pp.57-65, 2018.
- [14] Datasheet Sentaurus TCAD Industry-Standard Process and Device Simulators, 2012. Available at https://www.synopsys.com/content/dam/synopsys/silicon/datasheets/sentaurus_ds.pdf
- [15] Sze, S.M. and Ng, K.K.: *Physics of Semiconductor Devices*. Wiley, New York, 2nd Edition, 2007.
- [16] Balepur S. Murthy & P. R. S. Rao, Frequency Dependence of Junction Capacitance, *IETE Journal of Research*, 17(7), 273-276, 1971.
- [17] A. E. Papa, K. Kordás, G. Tóth, J. Levoska, A. Uusimäki, J. Vähäkangas, and S. Leppävuori, Thermal oxidation of porous silicon: Study on structure, *Applied Physics Letters* 86(4), 2005.
- [18] Rahul Yadav, Piyush N. Patel, Rantesh Kumari, V. N. Lad, "Development of a Metallic Photonic Bandgap-Inspired Probe for Detection of Weak Basic Dissociation Constant Drug in Bio-Fluid," *IEEE Sensor Journal*, vol. 17, no. 17, 5410-5418, 2017.

EVENTS OF THE TERM

A wide and diversified range of extracurricular activities exists on GGP, SURAT campuses students become involved in extracurricular activities not only for entertainment, social, and enjoyment purposes, but most important, to gain and improve skills and offer many social opportunities while also promoting service.

Various online and offline Events are Held at institute which can be very helpful in OVER this covid -19 pandemic situation.

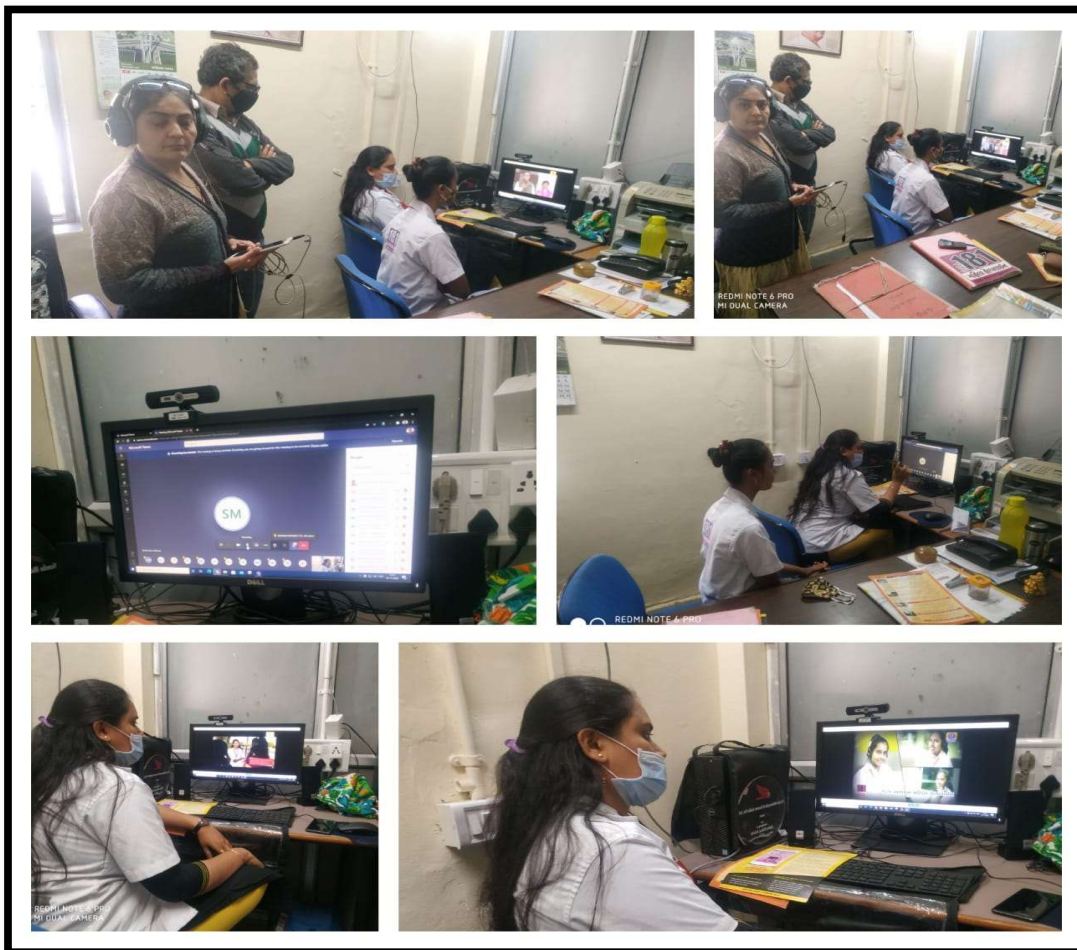
Code of Conduct: OFFLINE: G.P.G., SURAT/ ONLINE -Microsoft Team

Date: 23-12-2020 Event Name: TREE PLANTATION BY ALLUMINI



Date: 29-12-2020 Event Name: WEBINAR FOR 181 ABHAYAM HELP LINE

Description of the Event: Under NSS, our institute has Organized online webinar on Women Awareness programme about " 181 Abhyam Helpline " about How the Help line works to help the women? What can we do when suffering from some critical situation?..etc. Means women's social, physical, mental problems.



Date: 04_01_2021 Event Name: EXAM FOR NCC 2020 ADMITTED STUDENT



Date: 26-01-2021 Event Name: Republic Day Celebration



Date: 04_02_2021 Event Name: TRAFFIC AWARENESS

Description: A webinar on the topic “Traffic Awareness 2021” by Gujarat state Traffic police has been arranged for all the students of GPG, Surat.



Date: 10-02-2021 Event Name: FIRE SAFETY DEMO



STUDENT CORNER



JHA SAKSHI MAHARSHI
Enrollment No. : 196150311008 (4TH Semester)
Department of Electronics and communication
Engineering



A beautiful pencil sketch done by Jha Shakshi Maharshi.