

A PRACTICAL APPROACH OF CMOS INTEGRATED CIRCUITS WITH PC TOOLS DSCH2 AND MICROWIND 2

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ABSTRACT

The present paper introduces the design and simulation of CMOS integrated circuits, in PC tools DSCH and MICROWIND Version 2.6. Which will help for users not only analysis of VLSI subject but also research and practical approach from circuit to simulation.

I. INTRODUCTION

This paper summarizes various MOS device structure device modeling, simulation at logic and layout levels which include the CMOS Inverter, the 2D and 3D views, the comparative design in micron and deep-submicron technologies, the basic logic gates (AND, OR, XOR, complex gates), the arithmetic functions (Adder, comparator, multiplier, ALU) also the latches and memories.

1.1 About Dsch (Version 2.6)

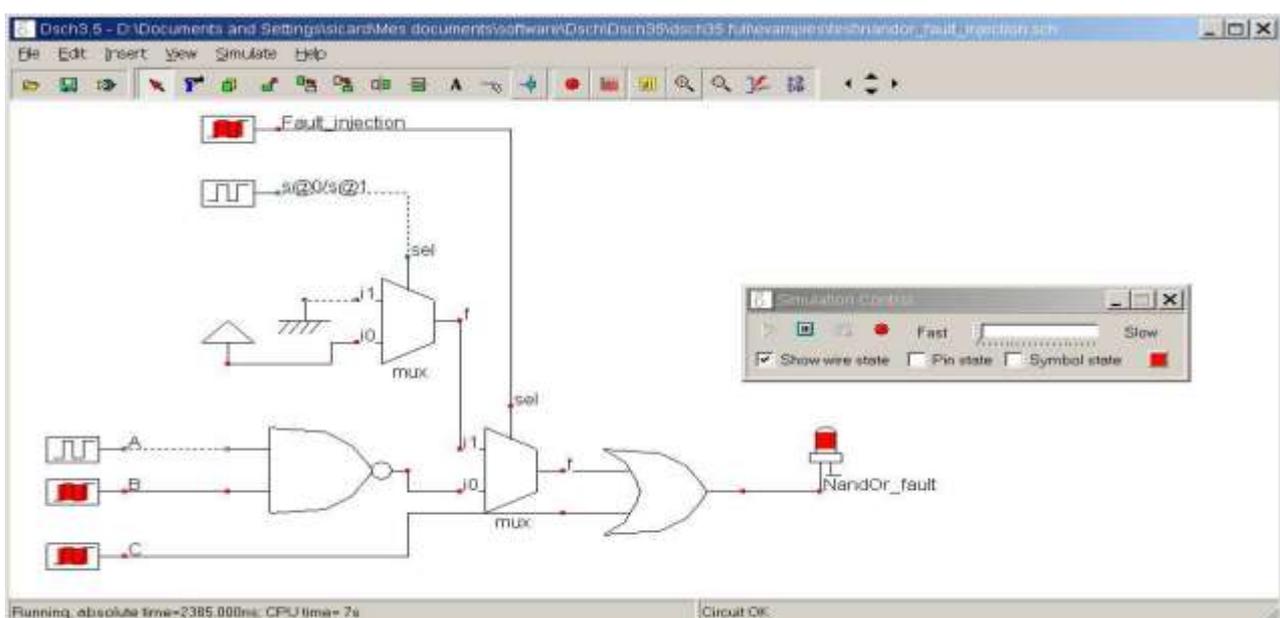


Fig. 1 View of Circuit simulator model in DSCH

The DSCH program is a logic editor and simulator. DSCH is used to validate the architecture of the logic circuit before the microelectronics design is started. DSCH provides a user-friendly environment for hierarchical logic design, and fast simulation with delay analysis, which allows the design and validation of complex logic structures. DSCH also features the symbols, models and assembly support for 8051 and 18f64 microcontrollers. DSCH also includes an interface to WinSPICE.

1.2 About Microwind (Version 2.6)

The MICROWIND program allows the student to design and simulate an integrated circuit at physical description level. The package contains a library of common logic and analog ICs to view and simulate. MICROWIND includes all the commands for a mask editor as well as original tools never gathered before in a single module (2D and 3D process view, Verilog compiler, tutorial on MOS devices). You can gain access to Circuit Simulation by pressing one single key. The electric extraction of your circuit is automatically performed and the analog simulator produces voltage and current curves immediately.

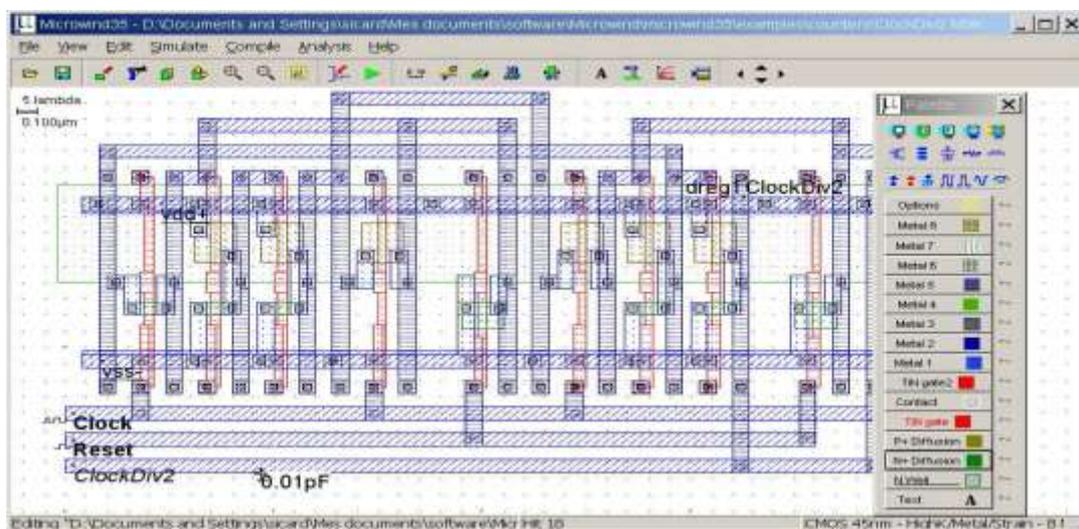


Fig. 2 View of Cricuit Layout model in Microwind

II. MOS LAYOUT IN MICROWIND

We use MICROWIND to draw the MOS layout
Double-click on the MICROWIND icon. The



and simulate its behavior.
MICROWIND display

window includes four main windows: the main menu, the layout display window, the icon menu and the layer palette. The layout window features a grid, scaled in lambda (\square) units. The lambda unit is fixed to half of the minimum available lithography of the technology. The default technology is a CMOS 8-metal layers 45 nm technology. In this technology, lambda is 0.02 μm (40 nm). The palette is located in the lower right corner of the screen. A red color indicates the current layer. Initially the selected layer in the palette is polysilicon. By using the procedure, we can create a manual design of the n-channel MOS.

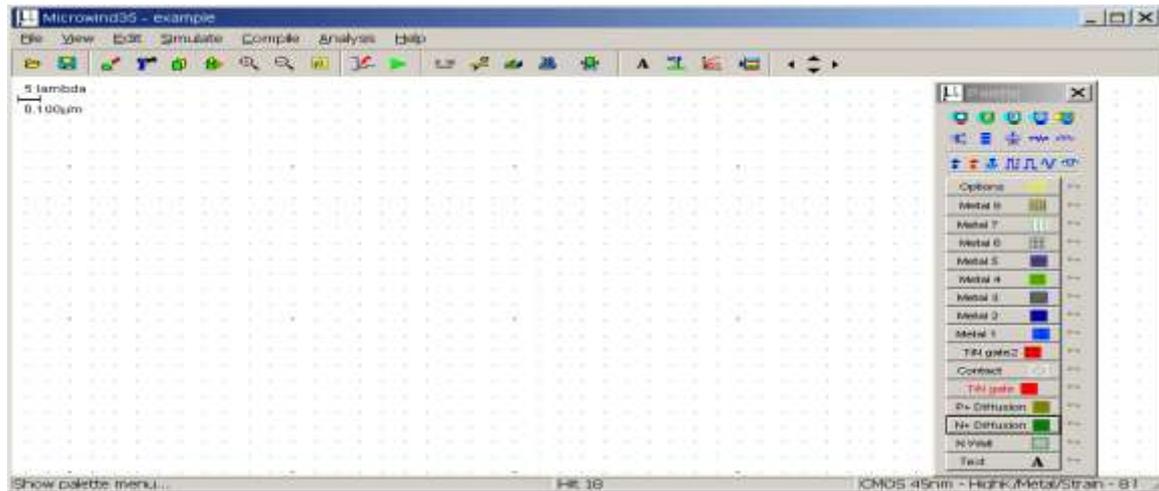


Figure 3- The Microwind window as it appears at the initialization stage

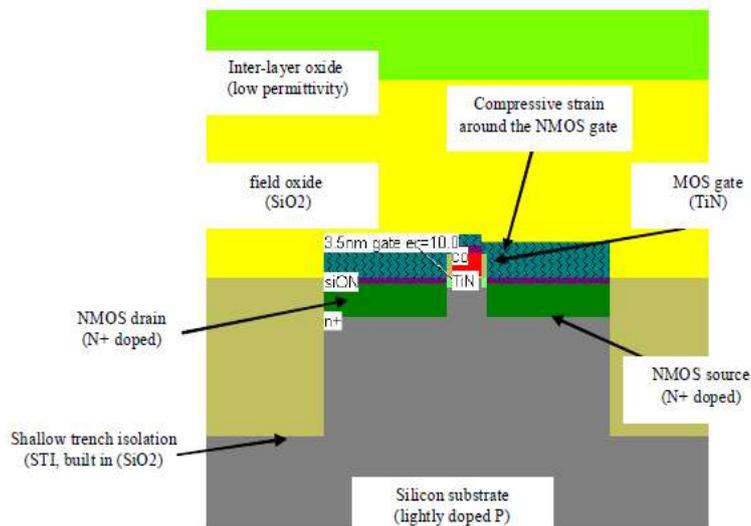
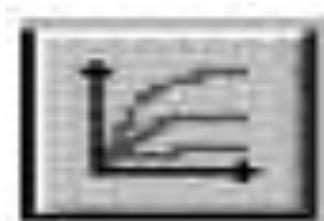


Figure 4-The cross-section of the nMOS devices.

2.1 Vertical aspect of the MOS



Click on this icon to access process simulation (Command Simulate Process section in 2D). The cross-section is given by a click of the mouse at the first point and the release of the mouse at the second point. In the example of Figure 4, three nodes appear in the cross-section of the n-channel MOS device: the gate (red), the left diffusion called source (green) and the right diffusion called drain (green), over a substrate (gray). A thin oxide called the gate oxide isolates the gate. Various steps of oxidation have lead to stacked oxides on the top of the gate.



2.2 Static Mos Characteristics

Click on the MOS characteristics icon. The screen shown in Figure 2-5 appears. It represents the I_d/V_d static characteristics of the nMOS device. The MOS size (width and length of the channel situated at the intersection of the polysilicon gate and the diffusion) has a strong influence on the value of the current. In Figure 2-5, the MOS width is 580 nm and the length is 40 nm. A high gate voltage ($V_g = 1.0V$) corresponds to the highest I_d/V_d curve. For $V_g=0$, almost no current flows, I_{ds} is close to 0. You may change the voltage values of V_d , V_g , V_s by using the voltage cursors situated on the right side of the window.

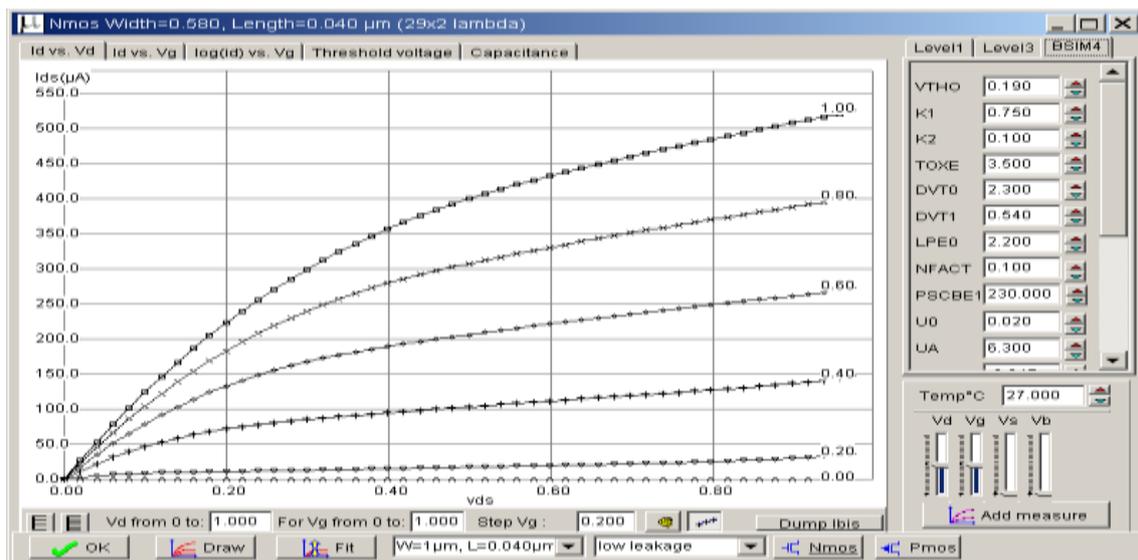
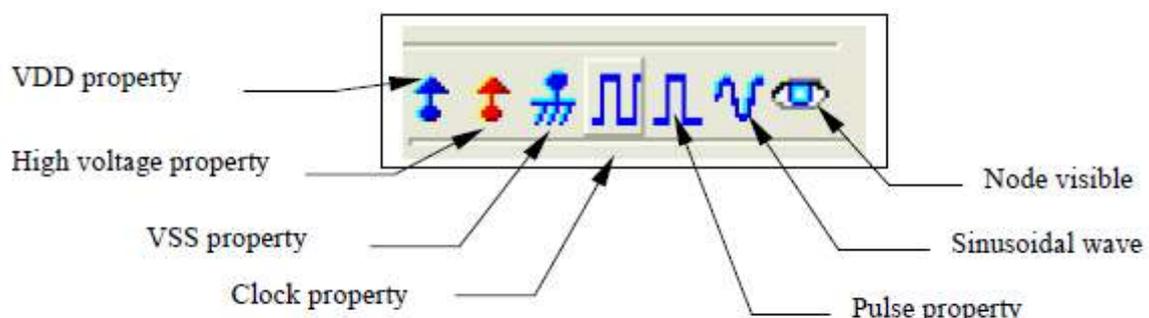


Figure 5 : N-Channel Mos Characteristics

2.3 Dynamic MOS behavior

The most convenient way to operate the MOS is to apply a clock to the gate, another to the source and to observe the drain. The summary of available properties that can be added to the layout is reported below.

2.3.1 Apply a clock to the gate. Click on the Clock icon and then, click on the polysilicon gate. The clock menu appears again. Change the name into V_{gate} and click on OK to apply a clock with 0.1 ns period (45 ps at “0”, 5 ps rise, 45 ps at “1”, 5 ps fall).



2.3.2 Apply a clock to the drain. Click on the Clock icon, click on the left diffusion. The Clock menu appears. Change the name into V_{drain} and click on OK. A default clock with 0.2 ns period is generated. The Clock property is sent to the node and appears at the right hand side of the desired location with the name V_{drain} .

2.3.3 Watch the output: Click on the Visible icon and then, click on the right diffusion. Click OK. The Visible property is then sent to the node. The associated text s1 is in italic, meaning that the waveform of this node will appear at the next simulation

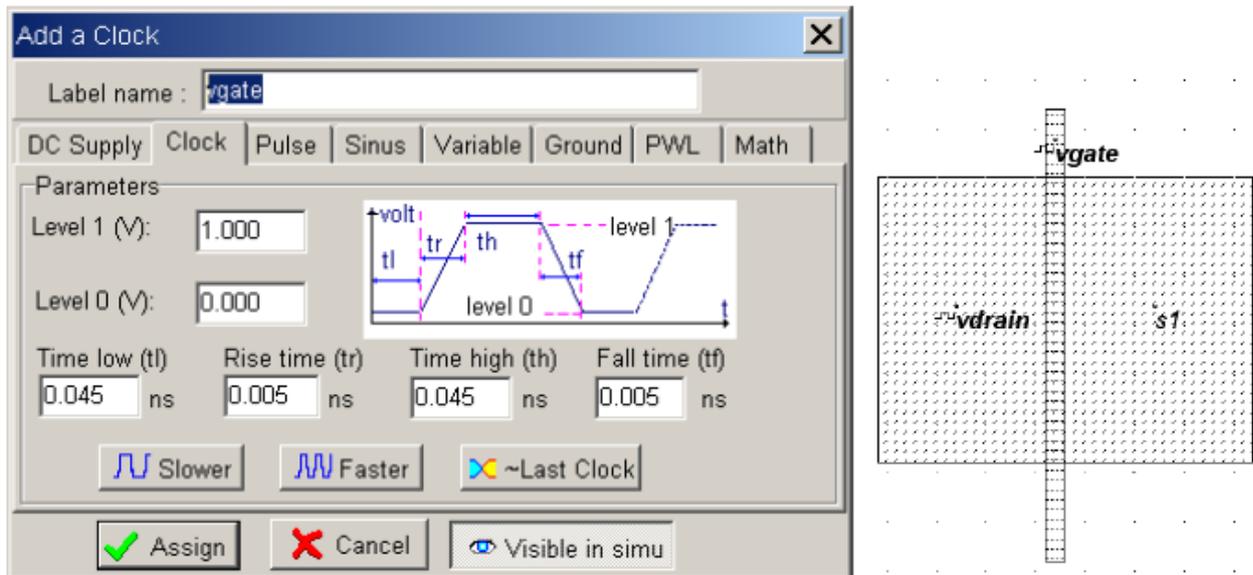


Figure 6: The Clock Menu And The Clock Property Insertion Directly On The Mos Layout

Always save BEFORE any simulation. The analog simulation algorithm may cause run-time errors leading to a loss of layout information. Click on File > Save as. A new window appears, into which you enter the design name. Type for example Mosn.MSK. Then click on Save. The design is saved under that filename

2.3.4 Analog Simulation

Click on Simulate > start Simulation. The timing diagrams of the nMOS device appear, as shown in Figure 7 Select the appropriate time scale (500 ps) to see the chronograms of the simulation. Click “Reset” to restart simulation at any time.

When vgate is at zero, no channel exists so the node vsource is disconnected from the drain. When the gate is on (vgate=1.0 V), the source copies the drain. It can be observed that the nMOS device drives well at zero but poorly at the high voltage. The highest value of vsource is around 0.6 V, that is VDD minus the threshold voltage.

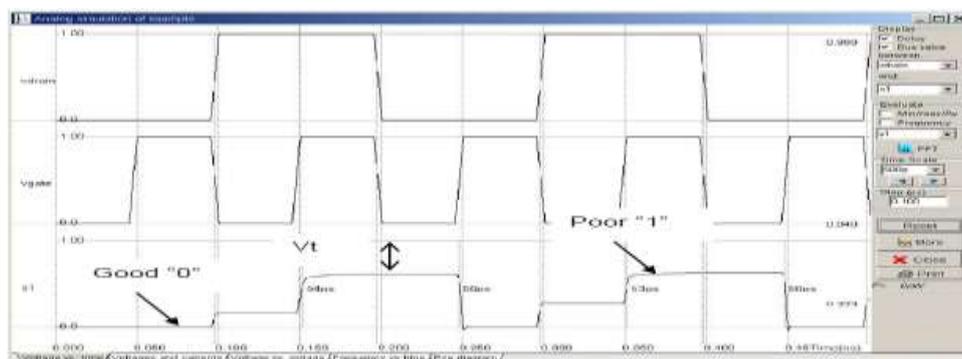


Figure 7: Analog simulation of the MOS device

III. THE CMOS INVERTER

First we can create CMOS Inverter circuit in DSCH software double clicking it located in the installed directory of dsch2 The following Screen will be appeared

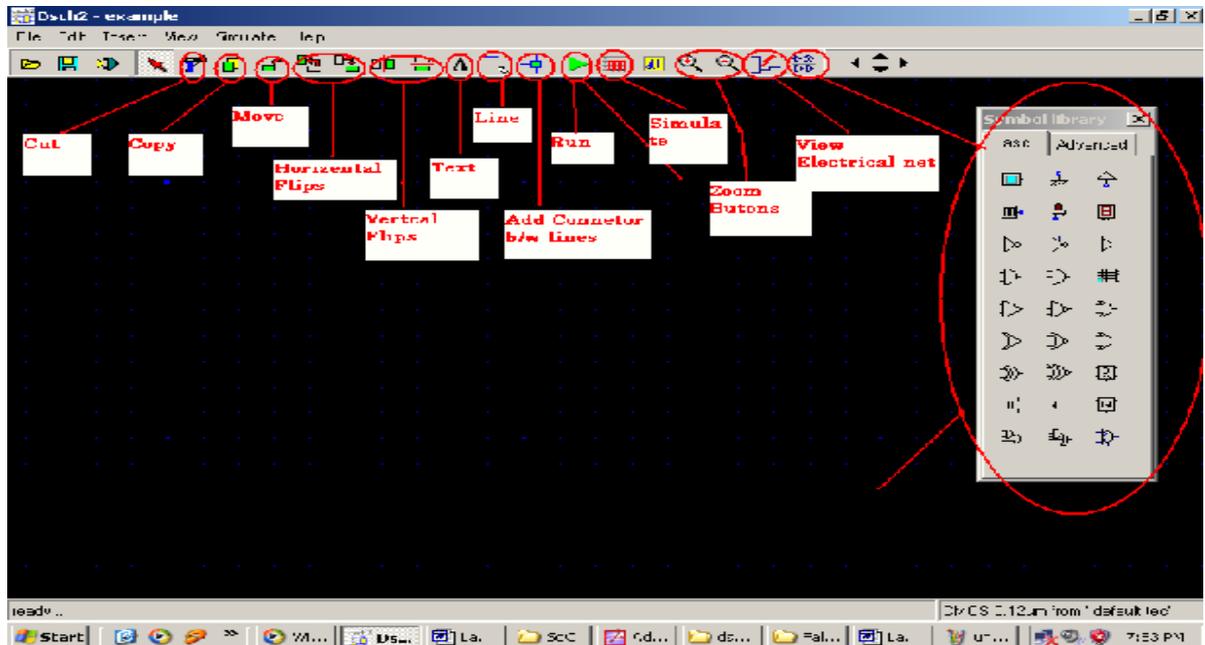


Figure 8: Main Window DSCH

3.1 Click on the pMOS and nMOS symbol button in the Symbol Library and drag it the schematic design areas as indicated in the figure.

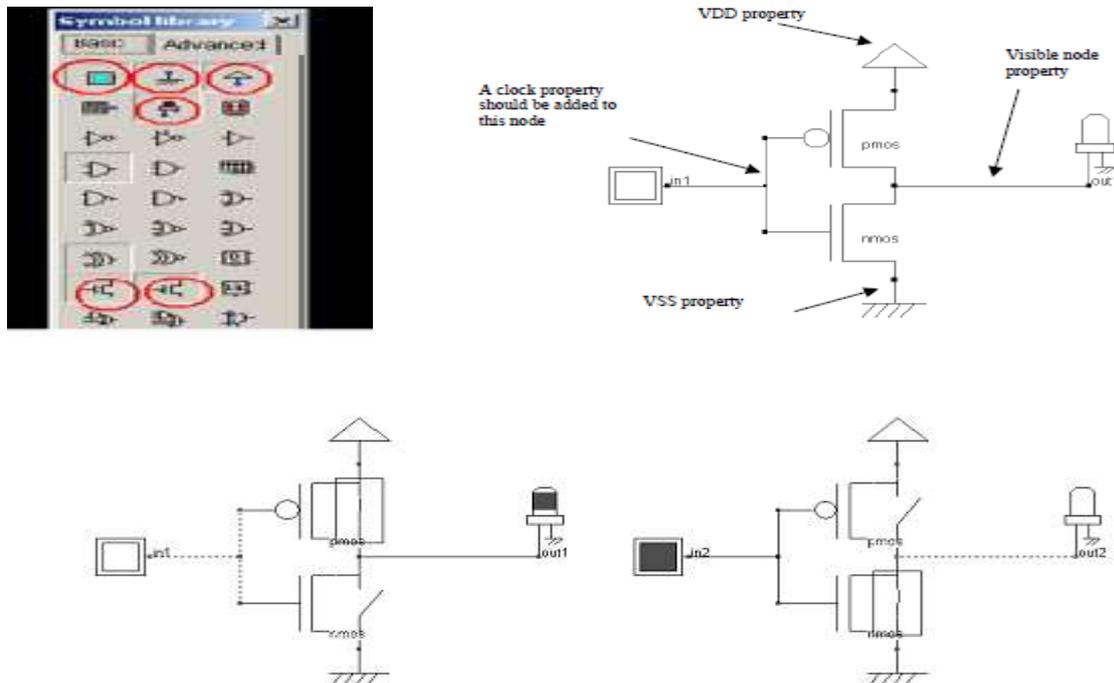


Figure 9: Simulating Schematic of CMOS Inverter in DSCH

3.2 The CMOS inverter design is detailed in the figure below. Here the p-channel MOS and the n-channel MOS transistors function as switches. When the input signal is logic 0 (Figure 10-a), the nMOS is switched off while PMOS passes VDD through the output. When the input signal is logic 1 (Figure 10-b right), the pMOS is switched off while the nMOS passes VSS to the output.

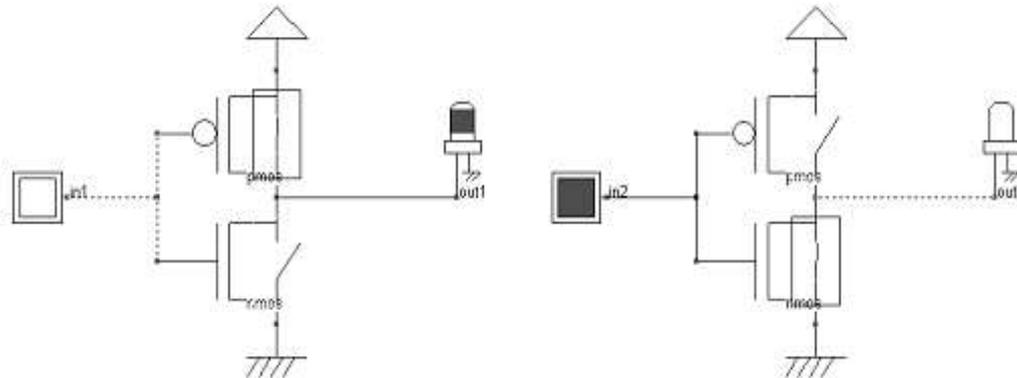


Figure 10-a **Figure 10-b : The MOS Inverter (File CmosInv.sch)**

3.3 Manual Layout of the Inverter

Click the icon MOS generator on the palette. The following window appears. By default the proposed length is the minimum length available in the technology (2 lambda), and the width is 10 lambda. In 45-nm technology, where lambda is 20 nm (0.02 μm), the corresponding size is 0.02 μm for the length and 0.04 μm for the width. Simply click Generate Device, and click on the middle of the screen to fix the MOS device.

Click again the icon MOS generator on the palette. Change the type of device by a tick on p-channel, and click Generate Device. Click on the top of the nMOS to fix the pMOS device.

The MOS generator is the safest way to create a MOS device compliant to design rules. The programmable parameters are the MOS width, length, the number of gates in parallel and the type of device (n-channel or p-channel). By default metal interconnects and contacts are added to the drain and source of the MOS. We can add a supplementary metal 2 interconnect on the top of metal 1 for drain and source.

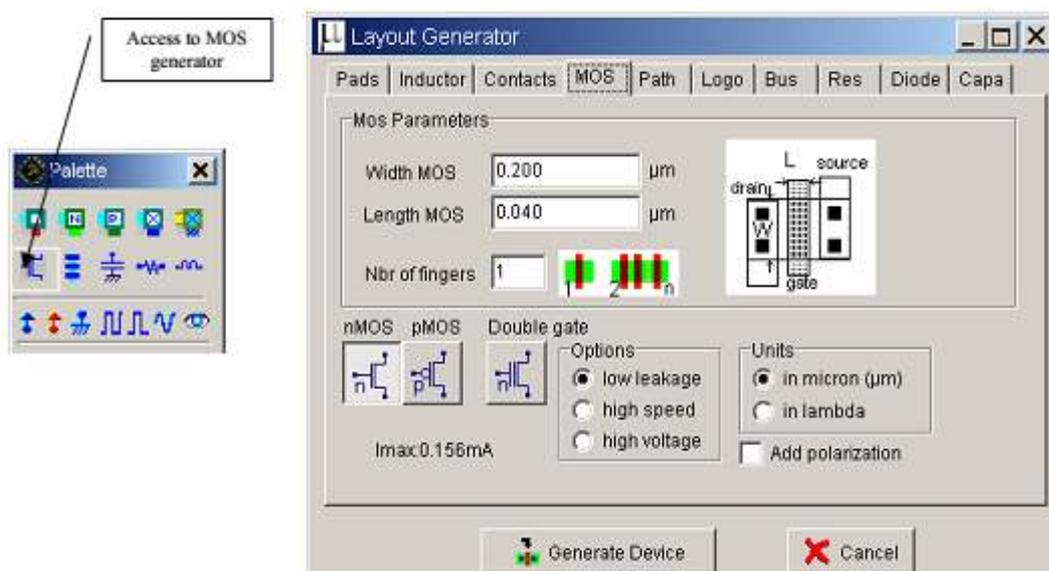


Figure 11 : Generating a nMOS device

3.4 Connection between Devices

Within CMOS cells, metal and polysilicon are used as interconnects for signals. Metal is a much better conductor than polysilicon. Consequently, polysilicon is only used to interconnect gates, such as the bridge between pMOS and nMOS gates, as described in the schematic diagram of figure 13. Polysilicon is rarely used for long interconnects, except if a huge resistance value is expected.

In the layout shown in figure 13, the polysilicon

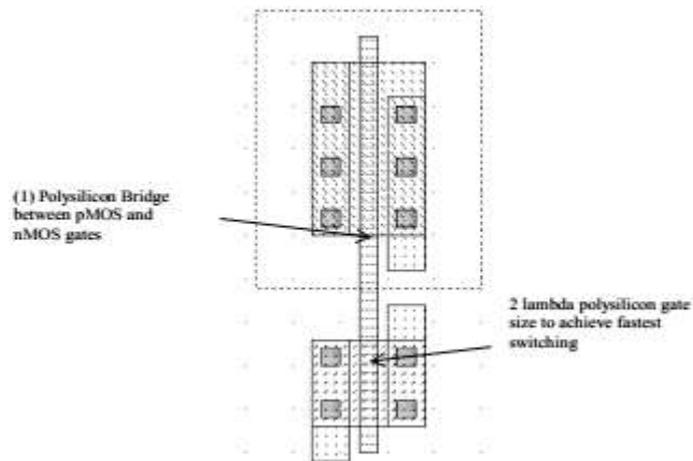


Figure 13 : Polysilicon bridge between nMOS and pMOS devices

bridge links the gate of the n-channel MOS with the gate of the p-channel MOS device. The polysilicon serves as the gate control and the bridge between MOS gates.

3.5 Save respective file and make verilog file with same destination and Open Microwind software go to Compile with same row width limit and compile it.

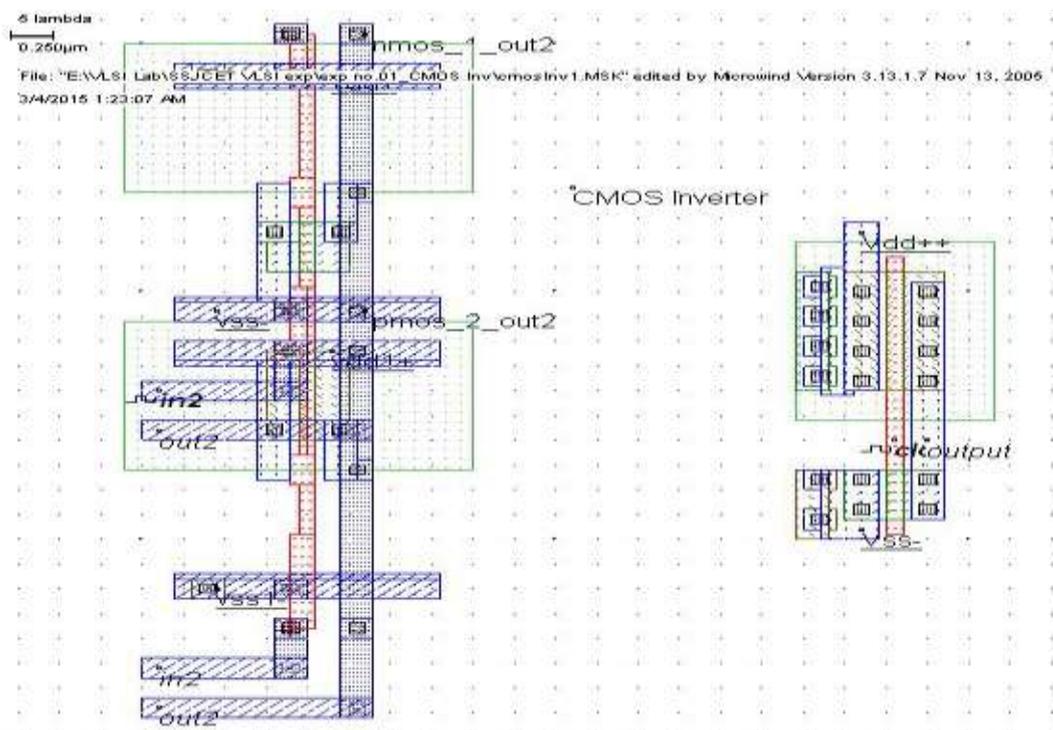


Figure 14: Layout of CMOS Inverter in Microwind

3.6 Useful Editing Tools

The following commands may help you in the layout design and verification processes.

Command	Icon/Short cut	Menu	Description
UNDO	CTRL+U	Edit menu	Cancels the last editing operation
DELETE	 CTRL+X	Edit menu	Erases some layout included in the given area or pointed by the mouse.
STRETCH		Edit menu	Changes the size of one box, or moves the layout included in the given area.
COPY	 CTRL+C	Edit Menu	Copies the layout included in the given area.
VIEW ELECTRICAL NODE	 CTRL+N	View Menu	Verifies the electrical net connections.
2D CROSS-SECTION		Simulate Menu	Shows the aspect of the circuit in vertical cross-section.

Figure 15 : A set of useful editing tools

3.7 Process steps to build the Inverter

At that point, it might be interesting to illustrate the steps of fabrication as they would sequence in a foundry. MICROWIND includes a 3D process viewer for that purpose. Click Simulate →Process steps in 3D. The simulation of the CMOS fabrication process is performed, step by step by a click on Next Step. On figure 3-13, the picture on the left represents the nMOS device, pMOS device, common polysilicon gate and contacts. The picture on the right represents the same portion of layout with the metal layers stacked on top of the active devices.

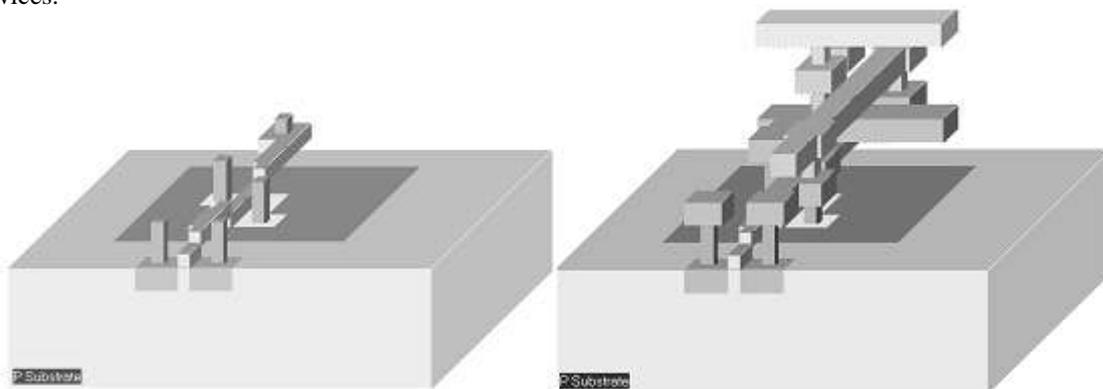


Figure 16 : The step-by-step fabrication of the Inverter circuit

3.6 The command Simulate →Run Simulation gives access to the analog simulation. Select the simulation mode Voltage vs. Time. The analog simulation of the circuit is performed. The time domain waveform, proposed by default, details the evolution of the voltages in1 and out1 versus time. This mode is also called transient simulation, as shown in figure 17 The truth-table is verified as follows. A logic “0” corresponds to 0 V a logic “1” to a 1.0 V. When the input rises to “1”, the output falls to “0”, with a 7 pico-second delay (7.10-12 second). The reason why the delay is larger before time 1.0 ns is that the circuit is “warming up” as the voltage supply suddenly rises from 0 to VDD at time= 0.0ns. The steady-state is reached at time=1.0 ns.

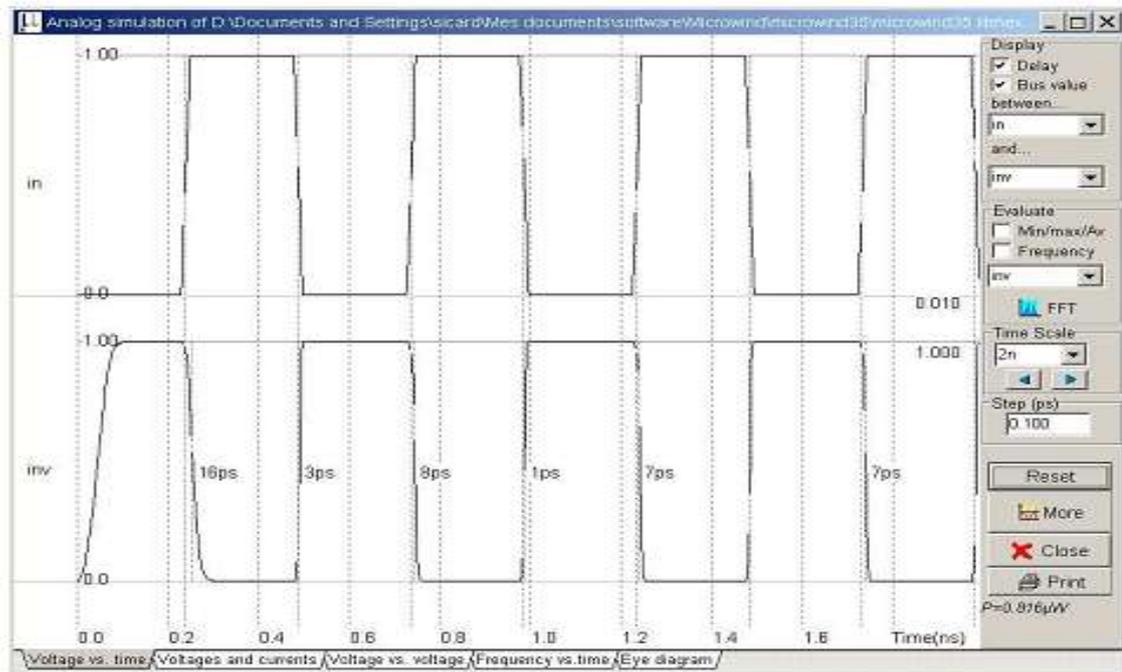


Figure 17 : Transient simulation of the CMOS inverter

IV. BASIC GATES

Here are some basic gates circuit diagram in dsch software and its layout in Microwind. The procedure all are same as explain above steps in CMOS inverter

4.1 The Nand Gate: The truth-table and logic symbol of the NAND gate with 2 inputs are shown below. In DSCH , select the NAND symbol in the palette, add two buttons and one lamp as shown above. Add interconnects if necessary to link the button and lamps to the cell pins. Verify the logic behaviour of the cell.

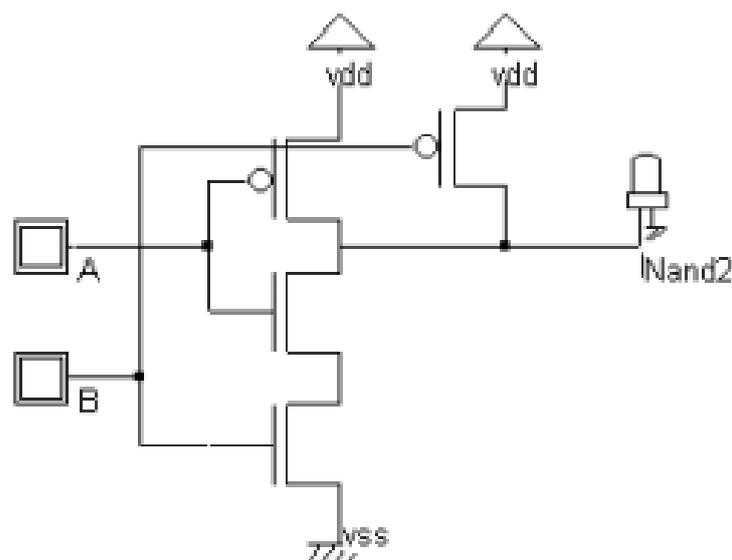


Figure 18: Schematic Diagram of the CMOS NAND Gate Design

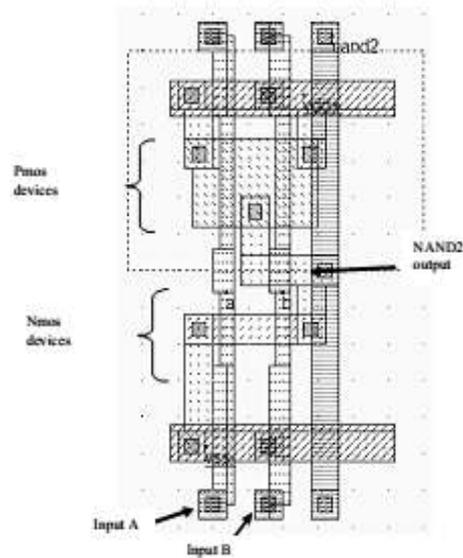


Figure 19 : A NAND cell created by the CMOS compiler.

4.2 The XOR Gate

There exist many possibilities for implementing the XOR function into CMOS. The least efficient design, but the most forward, consists in building the XOR logic circuit from its Boolean equation.

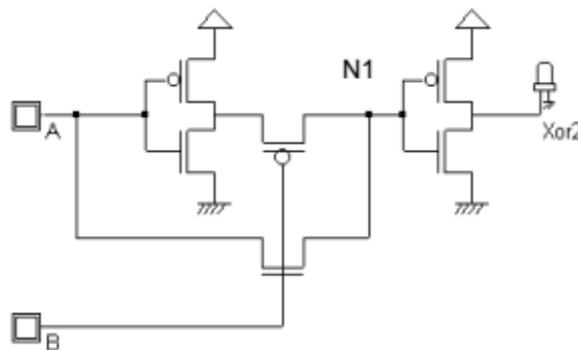


Figure 20 : The schematic diagram of the XOR gate

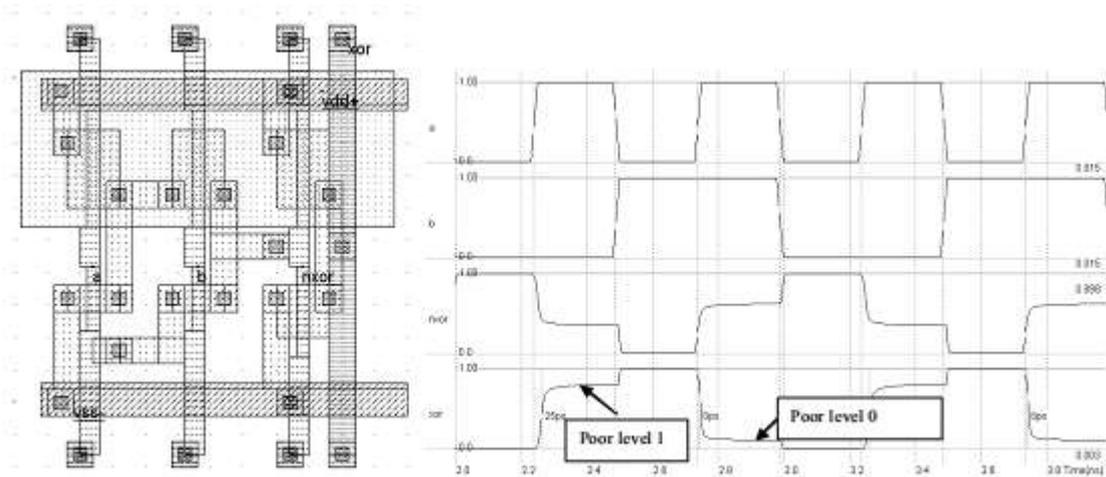


Figure 21 : Layout and simulation of the XOR gate

4.3 Silicon Menu

The software “silicon” is able to give a user’s controlled 3D view of silicon atoms such as SiO₂ (figure 22). The 3D view of the lattice shown in figure 12-2 shows the regular aspect of Si atoms and the very specific properties of the material. One boron atom acts as a dopant in the structure.

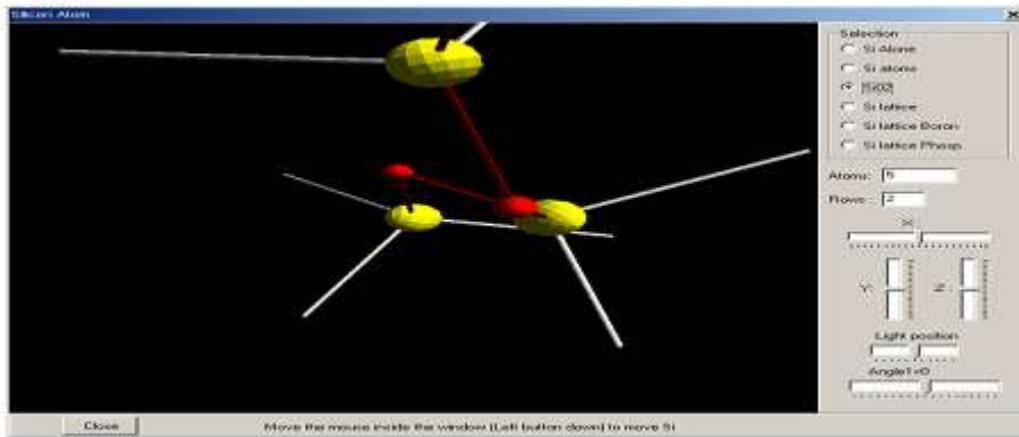


Figure 22 : The « silicon » main menu

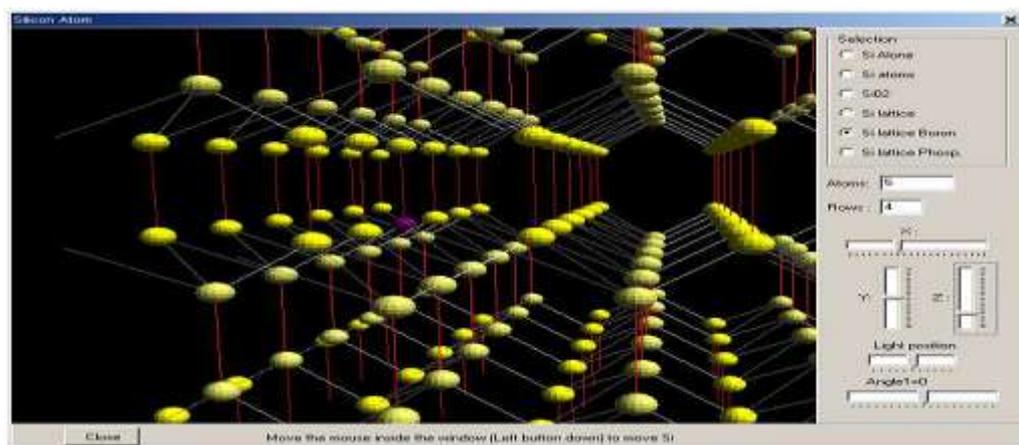


Figure 23 : The silicon lattice and a boron dopant

V. CONCLUSIONS

Since it is a practical approach of CMOS integrated circuit but its not limited for cmos gate or its respective circuit. We can use dsch and Microwind pc tools for microcontroller simulation and with using verilog file which is compile in microwind software.

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- [2] Sung-Mo Kang and Yusuf Leblebici, “CMOS Digital Integrated Circuits Analysis and Design”, Tata McGraw Hill, 3rd Edition, 2012.
- [3] Jan M. Rabaey, Anantha Chandrakasan and Borivoje Nikolic, “Digital Integrated Circuits: A Design Perspective”, Pearson Education, 2nd Edition.

[4] Microwind & Dsch Version 3.5 User's Manual Lite Version September 2009 by Etienne Sicard

WEB INFORMATION

[1] www.microwind.org for general information about MICROWIND

[2] www.microwind.net to download the lite version and order the professional version

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