Reliability Analysis of Comparator: NBTI, PBTI, HCI, AGEING

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Abstract. In this research, we focus on analytical reliability assessment. The reliability of meticulous conditions of voltage, temperature and degradation will be reported to device bounds. Such as the same effect on analogue or digital device performance like Comparator cell and combined circuits. In this research article, we are challenged with some explore methodologies to scrutinize the impact of reliability on comparator circuits. The reliability evaluation under the parameters of "Positive Bias Temperature Instability *(PBTI),* Negative Bias Temperature Instability *(NBTI)* and Hot Carrier Injection *(HCI)*" are performed. In this analysis, we considered which MOSFET was the utmost pretentious and slightest pretentious by the comparator circuit. Like all analogue and digital circuits, reliability is a major issue has instigated in a circuit that does fades performances because it enhances the trap concerning the source and the drain of every specific MOSFET. Large-scale assessment reliability has shown that the effect of every single MOSFET leads to the misleading conduct of comparator and ultimately causing damages. The precision of the comparator is exposed to this research with varying aspects. The total simulation work is performed using the 45 nm technology cadence virtuoso.

Keywords: Reliability · Comparator · CMOS technology · HCI
NBTI · PBTI and ageing

1 Introduction

A serious threat to the expansion of Bias Temperature Instability (BTI) which alters the execution of the VLSI circuit designed by CMOS Technology. NBTI greatly affects the temperature performance parameters such as reliability problems, and the tolerance voltage of a transistor, and the saturation transconductance of PMOS current. Similarly, NMOS transistors are affected by PBTI, but the effect PBTI, VLSI circuit chip is less important compared to the effect of NBTI, in particular in the Si02 layer case. Including NBTI and PBTI have another reason to compromise the reliability of the Hot Carrier Injector (HCI). Reducing the device reduces the duration of PMOS and NMOS transistors and their functionality is significantly degraded.

As technology grows, the performance of the device is increased by decreasing the size of the transistors that affect the life of design. Reliability involves the capability of methods to preserve distinct behaves in wholly conditions. At this nanometre age, most manufacturing faults are contemporaneous and guilty for the destruction of the useful

S. Verma et al. (Eds.): CNC 2018, CCIS 839, pp. 606–619, 2019.
https://doi.org/10.1007/978-981-13-2372-0_54

life of the emblem. The procedure deviation requires changes in the properties of the transistor (length, width and thickness of the oxide in the manufacture of the emblem). In the variant of the process, there are labour constraints because of nanoscale technology identical degradation condition to 250 nm,180 nm and 45 nm, we have to moderate the screen, but we cannot proficient to reduce the screen as it is static by 135 nm screening scale.

This research paper deals with reliability, many problems to be identified mainly by the variation of PBTI, HCI and NBTI. In HCl, mutually PMOS and NMOS are concerned, in PBTI merely NMOS is distressed and PMOS influences traps merely in NBTI. Useful life is greatly reduced by the outflow current generated in the device and maximum of the circuits are confidence in the dispersion temperature. HCl affects the reliability of CMOS devices; causing the voltage rise below the threshold and reducing the carrier mobility, which is additional in NMOS transistor. While device layout is biased high Vds devices, HCI is a very reliant aspect. At NBTI once the voltage is pragmatic to the port of the PMOS designs, the tolerance voltage will increase. It quickens the rise in temperature and rises the dispersion current and the transverse current. PBTI is likewise a problem of reliability, although is less important in the performance of the design.

In technology, VLSI expands portable design applications such as mobile phones, laptops, PDAs, electronic instruments and systems. The comparator means that it is used to compare two binary words for equality. Parameters, such as response speed and maximum bandwidth usage, are paid by operating amplifier architecture. The use of an op-amp as a comparator principal to an inefficient condition where the current transmission fraction is truncated. The reliability analysis has proven that it does contribute towards increasing the sensitivity of the comparator. Reliability has also proven that it could increase the vulnerability of the least sensitive parts of the comparator as disclosed in Fig. 1.

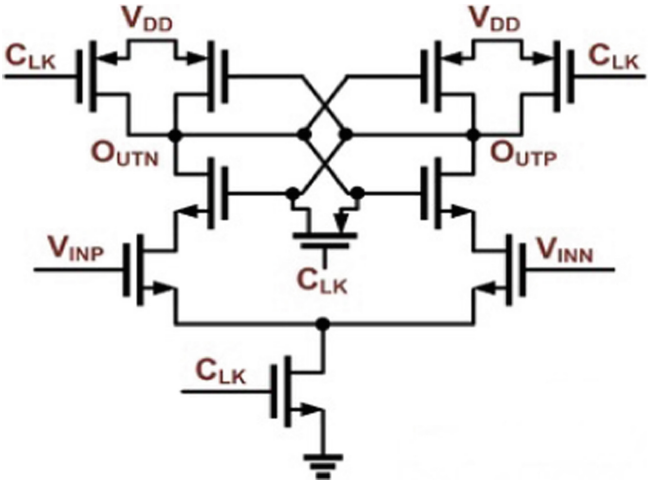

Fig. 1. CMOS design of comparator

2 Impact of PBTI on MOSFET

PBTI mainly occurs in NMOS devices since the operating voltage of the NMOS gate drain is largely positive or we can say that the NMOS device is affected positively (Vgs > 0) and has temperature dependence. PBTI effect is negligible compared to NBTI and HCI. It presents itself as a technology problem and metal gate High-K gate stack.

This problem occurs when negative carriers are trapped in the silicon/ oxide interface because the oxide or the voltage (Vgs > 0), a temperature dependence. You can see the support of negative movements.

PBTI (Positive Bias Temperature Instability) is alike to the simulated (hot-carrier injection) HCI, but there are different sets of model parameters and degradation life. If the parameters defined life PBTI, PBTI then the effects are simulated; On the other hand, they skipped. Both of these effects can be simulated HCl and PBTI together or separately. To stimulate PBTI, the following models are required of the oxide layers (Fig. 2).

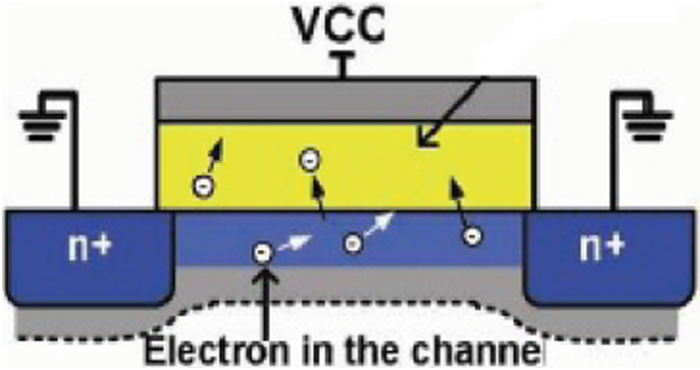

Fig. 2. Movement of carrier due to PBTI

3 Impact of NBTI on MOSFET

NBTI (Negative Bias Temperature Instability) affects the drain current, Vth, etc., of the PMOS transistors. Due to the variance in uniform band voltage, the NMOS transistor devises an insignificant even of holes accessible the feed and consequently, performs not endure from NBTI degradation.

In a PMOS transistor, here dualistic segments of NBTI contingent upon the bias ailment of the gate. During the phase 1 when $V_g = 0$ (i.e., $V_{gd} = -V_{dd}$), boundary traps are generated diffusing the hydrogen atoms broken from Si-H bonds near to the gate. This segment is stated as “stress” or “static NBTI”. In segment 2, when $V_g = V_{dd}$ (i.e., $V_{gs} = 0$), the PMOS device is under pure recovery as hydrogen atoms closer to the interface dispersed in return to the boundary and strengthen the wrecked Si-H bonds.

This segment is stated as "recovery" and has a momentous effect on the appraisal of NBTI during the forceful interchanging in digital operations. However, in analogue applications recovery is unlikely to happen as the transistors are always undergoing stress when operating (Fig. 3).

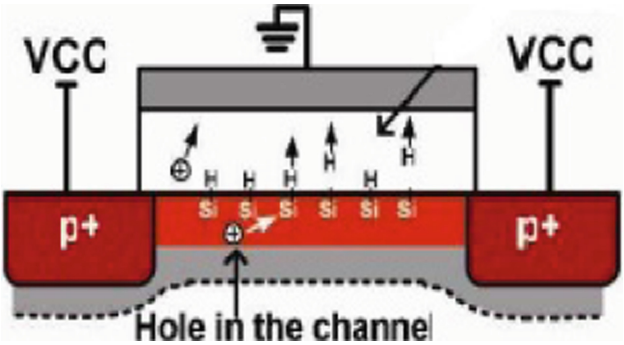

Fig. 3. Movement carrier due to NBTI

Based on this reaction-diffusion model and considering the simplest case, in which the gate is under a constant stress with a DC voltage, the shift of threshold voltage can be given by

$$\Delta V_t = (K_v^2 t)^n \tag{1}$$

where n is the period interpreter for NBTI which indicates the dilapidation rate. For a H_2 centered dissemination standard, $n = 1/6$ and for an H centered ideal, $n = 1/4$. Kv has an exponential necessity dependency on temperature (T) and electric field in the dielectric and this is called the static model.

$$K_v = \left(\frac{qt_{ox}}{E_{ox}}\right)^3 K^2 C_{ox}\left(V_{gs} - V_{th}\right)\sqrt{C}\exp\left(\frac{2E_{ox}}{E_0}\right) \tag{2}$$

Where q is electron charge, k is Boltzmann constant, Cox is the oxide capacitance per unit area, Eox is the vertical electric field across the oxide and tox is the oxide chunkiness.

4 Impact of HCI on MOSFET

Hot carrier injection is a further deprivation mechanism perceived in MOSFETs. The main source of heat on MOSFET's channel during circuit operation, rather than "anode", as anode-hole injection models. These powerful carriers can penetrate into the oxidation of the surface and the engendered electrons or holes privileged the channel or heating conductors. In this method, inoculated carriers spawn boundary or bulk oxide

deficiencies, and as a result, the MOSFET features such a way of as the initial voltage, etc. are reduced over time.

Hot carrier pressure circumstances are intrinsic in the CMOS circuit operation. Figure 1(a) illustrations the CMOS inverter with feedback terminal A and output terminal. When the Va is increased (VDD), the PMOS off experiences NMOS, TDDB pressure. NMOS's gate terminal, Vg = Va, low to high (= 0 V) switches, canal bias, Vd = Vb, increases. Vg ∼ Vd/2 (not VDD/2!), The NMOS goes through the maximum heat carrier pressure situation (given below). Finally, when the Va is low, the NMOS off and the PMOS belongs to NBTI and TDDB. This is a high-to-low low Va (which is not a constant DC component) which can contribute to HCI during inverter operation (Fig. 4).

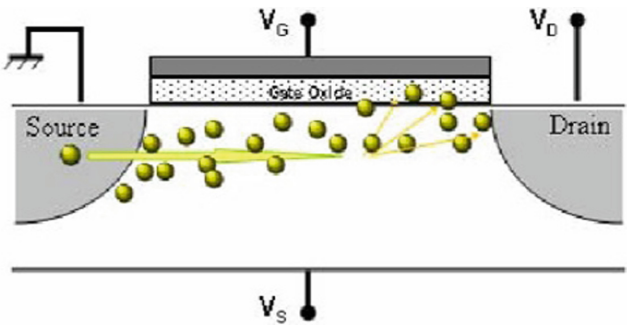

Fig. 4. Flow of carrier due to HCI

The degradation of hot-carrier models in MOS transistors includes:

- A model to calculate the current substrate (NMOSFET, PMOSFET) and gate (PMOSFET).
- A life model that calculates the Hot-carrier circuits that operate under experimental results in accelerated test conditions.
- Ageing model that describes the degradation characteristics of transistors in the voltage function: this model type parameters cadence model for simulation of degraded circuit performance degraded.

5 Simulated Reliability Graphs and Results

Reliability results are simulated for each NMOS & PMOS used in the simulated circuit. In this paper we simulated the parameters like NBTI, HCI and Ageing below the stress circumstances of Voltage, current and temperature. The result of PBTI was negligible so it has been neglected in the paper. Only HCI & NBTI effects are discussed. The circuit of comparator consists of 10 MOSFETS which are of 06 NMOS and 04 PMOS. This designed technology is known as CMOS technology.

5.1 Effect in PMOS Due to NBTI

From Table 1 it can be concluded that increasing supply voltage increases each PMOS transistor Vg & Vd values, which affects the threshold value Vth & saturation value Vsat of the circuit and its transistors (Figs. 5, 6, 7, 8, 9, 10, 11 and Tables 2, 3, 4).

Table 1. Presents the maximum absolute Vgs & Vds values of PMOS used in circuit at 0.7 V, 1 V & 1.5 V supply voltages for transistors under NBTI condition.

	Max Vg (V)			Max Vd (V)		
Volts→	0.70 V	1.0 V	1.20 V	0.70 V	1.0 V	1.20 V
PMOS↓						
PM1	7.01E−01	1.01E+00	1.21E+00	1.62E−01	2.81E−01	3.69E−01
PM2	1.6E−01	2.76E−01	3.62E−01	1.61E−01	2.81E−01	3.69E−01
PM3	1.64E−01	2.81E−01	3.69E−01	1.6E−01	2.76E−01	3.69E−01
PM4	7.01E−01	1.01E+00	1.21E+00	1.59E−01	2.76E−01	3.69E−01

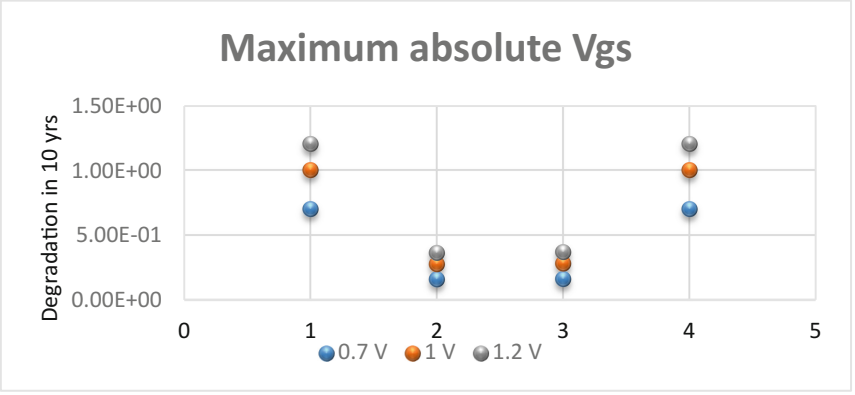

Fig. 5. Indicates the maximum absolute Vgs of PMOS

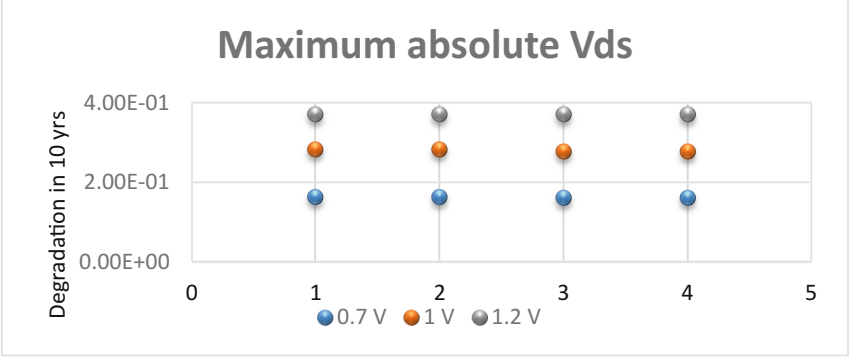

Fig. 6. Indicates the maximum absolute Vds of PMOS

Table 2. Presents the degradation of PMOS used in circuit at 0.7 V, 1.2 V supply voltages for transistors at the duration of 1Y, 5Y & 10Y under NBTI condition.

	0.7 V			1.2 V		
Time→	1Yrs	5Yrs	10Yrs	1Yrs	5Yrs	10Yrs
PMOS↓						
PM1	7.71E−01	4.51E−01	8.2E−01	7.1E−01	1.41E−01	9.2E−01
PM2	4.6E−02	3E−02	1.91E−01	7.32E−02	3.5E−01	5.5E−01
PM3	5.01E−02	4.01E−02	1.9E−01	8.52E−02	3.52E−01	5.71E−01
PM4	7.69E−01	4.51E−01	8.21E−01	7.22E−01	1.5E−01	9.31E−01

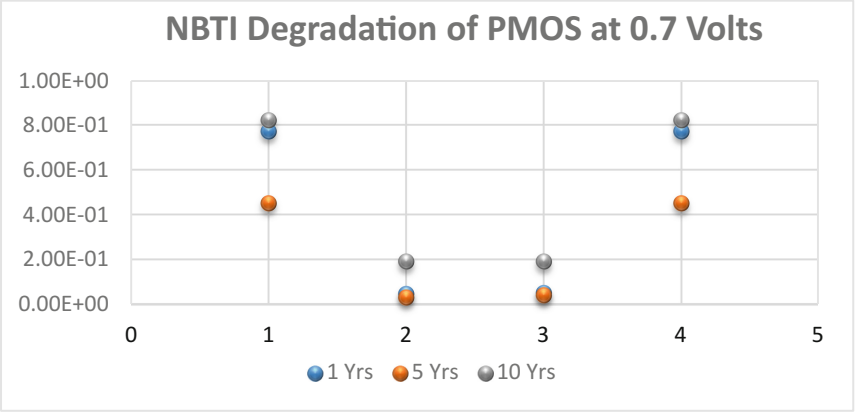

Fig. 7. Indicates the NBTI degradation of PMOS at 0.7 Volts

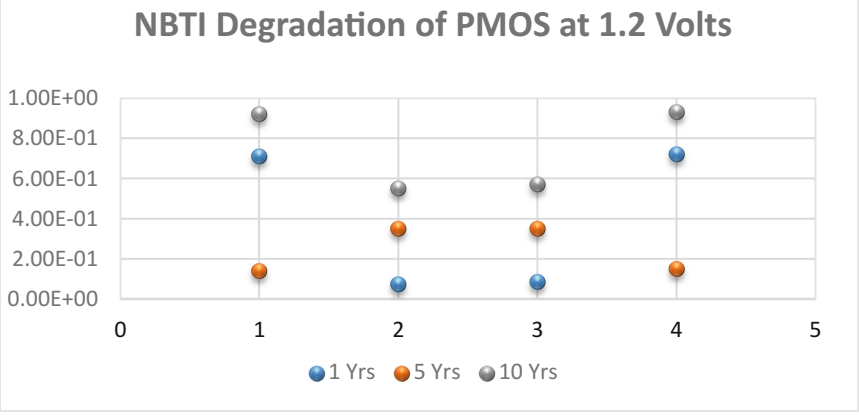

Fig. 8. Indicates the NBTI degradation of PMOS at 1.2 Volts

Table 3. Presents the ageing of PMOS used in circuit at 0.7 V, 1.2 V supply voltages for transistors at the duration of 1Y, 5Y & 10Y under NBTI condition.

	0.7 V			1.2 V		
Time→	1Yrs	5Yrs	10Yrs	1Yrs	5Yrs	10Yrs
PMOS↓						
PM1	2.18E−09	1.09E−08	2.18E−08	8.49E−08	4.25E−07	8.49E−07
PM2	4.60E−02	1.52E−10	3.04E−10	1.13E−10	5.63E−10	1.13E−09
PM3	3.11E−11	1.55E−10	3.11E−10	1.20E−10	5.99E−10	1.20E−09
PM4	3.04E−11	1.09E−08	2.19E−08	8.57E−08	4.29E−07	8.57E−07

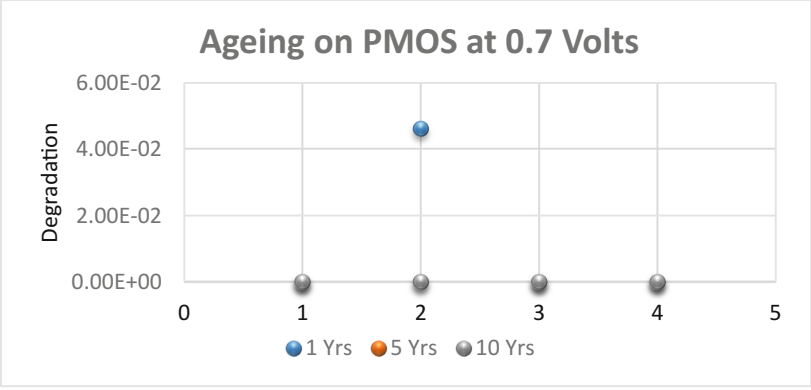

Fig. 9. Indicates the ageing on PMOS at 0.7 Volts

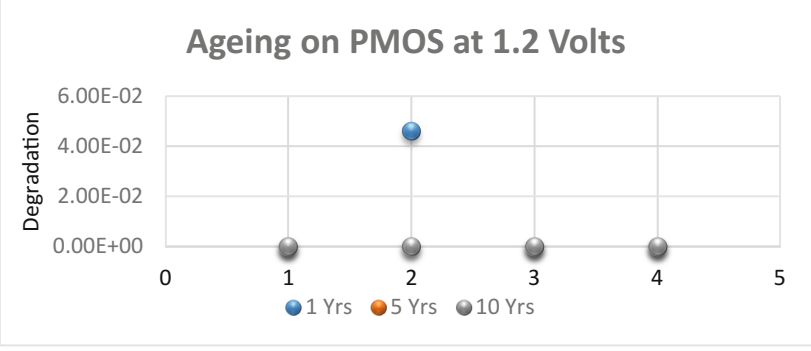

Fig. 10. Indicates the ageing on PMOS at 1.2 Volts

Table 4. Presents the Lifetime of PMOS used in circuit at 1.2 V supply voltages for transistors at the duration of 1Y, 5Y & 10Y under NBTI condition.

Time→	1 Yrs	5 Yrs	10 Yrs
PMOS↓			
PM1	5.210E+03	5.210E+03	5.210E+03
PM2	3.740E+05	3.740E+05	3.740E+05
PM3	3.660E+05	3.660E+05	3.660E+05
PM4	5.200E+03	5.200E+03	5.200E+03

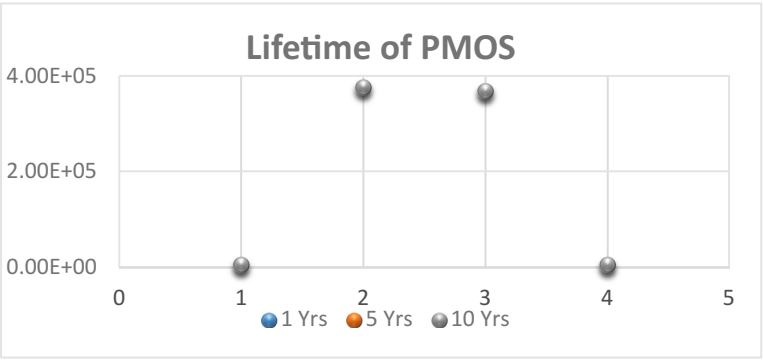

Fig. 11. Indicates the lifetime of PMOS

5.2 Effect in PMOS Due to HCI

See Table 5 and Figs. 12, 13.

Table 5. Presents the degradation of PMOS used in circuit at 0.7 V & 1.2 V supply voltages for transistors at the duration of 1Y, 5Y & 10Y under HCI condition.

	0.7 V			1.2 V		
Time→	1Yrs	5Yrs	10Yrs	1Yrs	5Yrs	10Yrs
PMOS↓						
PM1	1.77E−02	2.450E−02	2.820E−02	3.72E−02	5.150E−02	5.92E−02
PM2	7.46E−03	1.03E−02	1.19E−02	9.73E−03	1.35E−02	1.55E−02
PM3	7.50E−03	1.04E−02	1.19E−02	9.85E−03	1.36E−02	1.57E−02
PM4	1.77E−02	2.45E−02	2.82E−02	3.720E−02	5.160E−02	5.930E−02

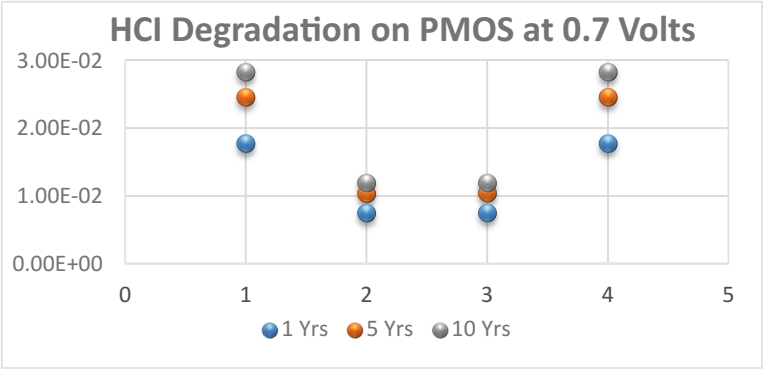

Fig. 12. Indicates the HCI degradation of PMOS at 0.7 V

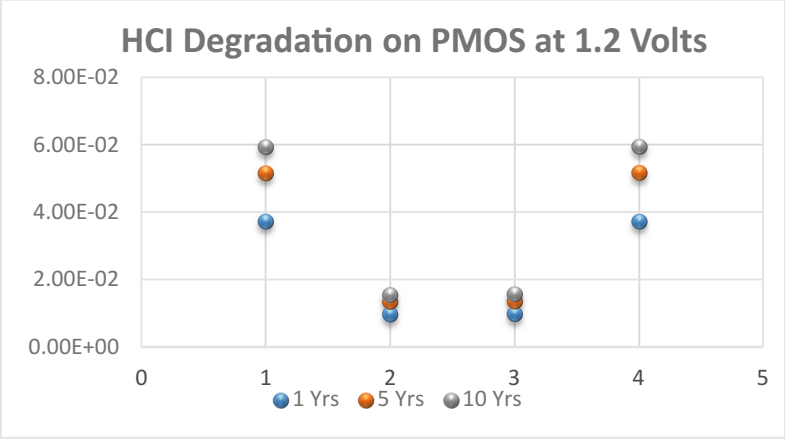

Fig. 13. Indicates the HCI degradation of PMOS at 1.2 Volts

5.3 Effect in NMOS Due to HCI

See Tables 6, 7 and Figs. 14, 15, 16, 17.

Table 6. Presents the degradation of NMOS used in circuit at 0.7 V, 1.2 V supply voltages for transistors at the duration of 1Y, 5Y & 10Y under HCI condition.

	0.7 V			1.2 V		
Time→	1Yrs	5Yrs	10Yrs	1Yrs	5Yrs	10Yrs
PMOS↓						
NM1	8.50E−27	1.59E−26	2.08E−26	0.0E+00	0.0E+00	0.0E+00
NM2	1.22E−29	2.29E−29	3.00E−29	2.17E−27	4.06E−27	5.32E−27
NM3	6.89E−27	1.29E−26	1.69E−26	6.22E−28	1.16E−27	1.53E−27
NM4	1.16E−26	2.18E−26	2.86E−26	5.79E−24	1.08E−23	1.42E−23
NM5	2.60E−29	4.86E−29	6.37E−29	0.0E+00	0.0E+00	0.0E+00
NM6	3.82E−22	7.15E−22	9.37E−22	1.89E−18	3.54E−18	4.64E−18

Table 7. Presents the ageing of NMOS used in circuit at 0.7 V, 1.2 V supply voltages for transistors at the duration of 1Y, 5Y & 10Y under HCI condition.

	0.7 V			1.2 V		
Time	1Yrs	5Yrs	10Yrs	1Yrs	5Yrs	10Yrs
NMOS						
NM1	1.29E−67	6.43E−67	1.29E−66	0.0E + 00	0.0E + 00	0.0E + 00
NM2	6.54E−75	3.27E−74	6.54E−74	3.87E−69	1.94E−68	3.87E−68
NM3	7.50E−68	3.75E−67	7.50E−67	1.57E−70	7.84E−70	1.57E−69
NM4	2.89E−67	1.44E−66	2.89E−66	2.39E−60	1.20E−59	2.39E−59
NM5	4.54E−74	2.27E−73	4.54E−73	0.0E+00	0.0E+00	0.0E+00
NM6	1.12E−55	5.58E−55	1.12E−54	3.36E−46	1.68E−45	3.36E−45

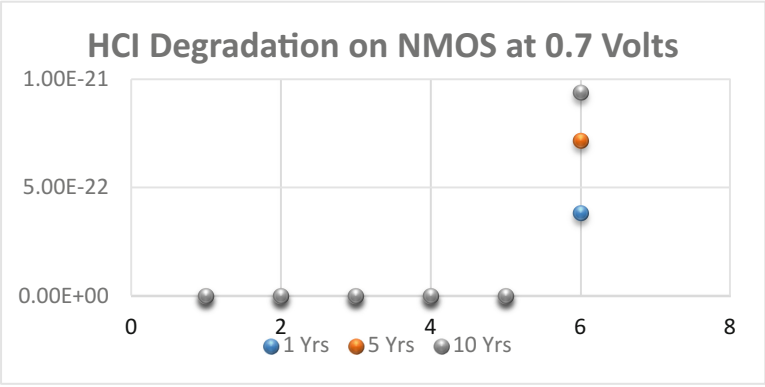

Fig. 14. Indicates the HCI degradation of NMOS at 0.7 Volts

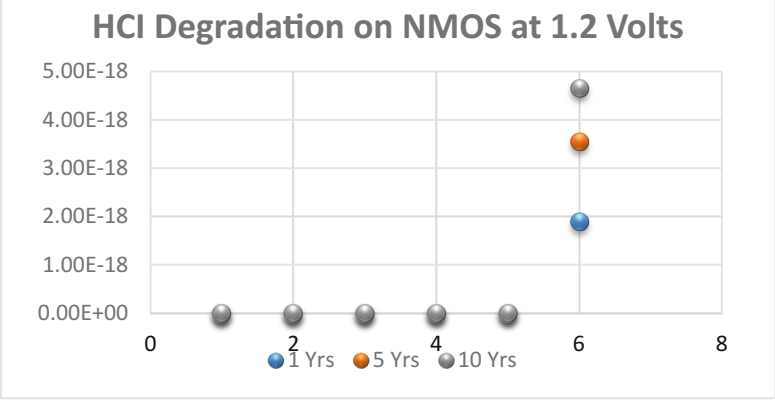

Fig. 15. Indicates the HCI degradation of NMOS at 1.2 Volts

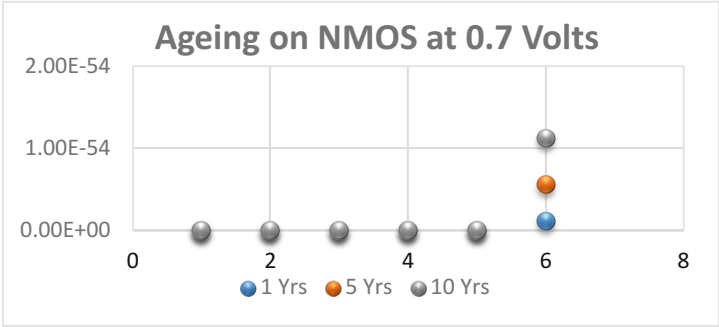

Fig. 16. Indicates the ageing on NMOS at 0.7 Volts

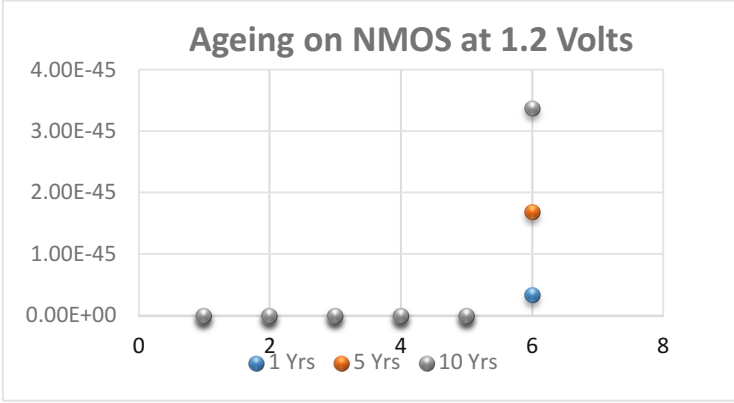

Fig. 17. Indicates the ageing on NMOS at 1.2 Volts

6 Conclusion

Here, PBTI, NBTI and HCI represent a challenge for reliability issues with nano-scale CMOS technologies. Concerning this article we explored the consequences of NBTI, PBTI and HCI on the Comparator under the conditions of degradation, lifetime and aging in the altered years with various stressed voltages. We have concluded that the effect of HCI and NBTI increases the time and voltage output and respectively is an increase in Vth value that reduces the lifetime of PMOS and NMOS transistors and degrades them to some values that say changes in Isub, Ig, and lifetime.

Acknowledgment. I would like to thanks ITM University for providing the Cadence Virtuoso Tool of 45 nm Technology.

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