Phase Change Memory (PCM) Using COMSOL Multiphysics

SOURAV DAS, ID: 18-37400-1-1, Email: sdhriday77@gmail.com@gmail.com,
MOON TANSIR MAMUN, ID:18-37315-1, Email: moontansir@gmail.com,
MAHMUDUL HASSAN, ID:18-37380-1, Email: mahmudulhassan1901@gmail.com,
ABDULLAH AL NOMAN, ID: 17-34751-2, Email: abdullah.noman3222@gmail.com,
REDWAN ISLAM,ID: 17-35146-2, Email: redwanislamsiam@gmail.com,
FAIZUL KARIM POLASH, ID: 18-36315-1 , Email:fk.polash98@gmail.com,
Department of Electrical and Electronic Engineering, American International University-Bangladesh (AIUB) 408/1, Kuratoli, Khilkhet, Dhaka 1229, Bangladesh,

***Abstract*— With a choice of reset procedure on a mushroom cell as model, this paper portrays the Phase Change Memory(PCM) demonstrating with COMSOL Multiphasics programming. By examining COMSOL Multiphysics displaying results and hypothetical estimations of common models, the legitimacy and possibility of Phase Change Memory(PCM) in COMSOL Multiphysics is demonstrated. Because of the thermoelectric warmth and flow in the PCM cell, the outcome is altogether modified the temperature circulation close to the dynamic locale. Expected outcome is gotten in reset procedure on a Ge2Sb2Te5 (GST) mushroom cell. Warm and electric protection is led among Tin and SiO2 likewise in the middle of SiO2 and GST mushroom offer to show signs of improvement anticipated yield.**

Keywords- ***COMSOL® Multiphysics, Phase Change Memory(PCM), Ge2Sb2Te5 (GST), TiN, Random Access Memory(RAM), MOSFET, Peltier***

I. INTRODUCTION

In this paper, the reset operation on a mushroom cell of PCM is investigated analyzed with COMSOL Multiphysics. Thermoelectric effect on PCM elements can be analyzed by the simulations of reset operation on a Ge2Sb2Te5 (GST) mushroom cell. Mainly this paper is written to capture the electro thermal situation taking place in PCM operation using the COMSOL Multiphysics. COMSOL simulation is done to observe the set and reset operation of PCM (Phase change memory) details about PCM. According to observation on operation of PCM contribution of thermoelectric effect and impact of voltage polarity is analyzed in the paper. To see the heating and cooling process, the Heat Transfer Module is used.

COMSOL Multiphysics is a cross-stage limited component examination, solver and Multiphysics recreation programming. It orchestrated with true applications. All impacts that are seen as a general rule can be developed and applied in recreation. To do this Multiphysics is required. It likewise offers admittance to predefined material libraries in different material science spaces and it can include custom materials too. It is fundamentally CAD or Maya yet for material science individuals. This is numerous logical models that is comprise of the things that you are keen on, for example, acoustics, electromagnetics, concoction responses, mechanics, liquid stream, and warmth move. COMSOL Multiphysics as the name recommends bargains in reenactment and displaying of Multiphysics components. State for instance for building a machine which has components of electromagnetic enlistment just as warmth move. So it tends to be effectively reenacting both the kinds of material science by building a model for machine

Also, new memory advances are showing up on the scene and they are beginning to have an effect in the market, empowering processor circuits to perform all the more adequately.

With innovation moving advances apace, not exclusively are the set up advances moving advances with SDRAM innovation moving from DDR3 to DDR4 and afterward to DDR5, yet Flash memory utilized in memory cards is likewise creating just like different advances.

The different memory types or memory technologies are available in the market. These are detailed below:

1. DRAM: Dynamic RAM is a type of arbitrary access memory. Measure utilizes a capacitor to store each piece of information, and the degree of charge on every capacitor decides if that bit is a sensible 1 or 0. Measure is the type of semiconductor memory that is regularly utilized in gear including PCs and workstations where it shapes the fundamental RAM for the PC. The semiconductor gadgets are typically accessible as incorporated circuits for use in PCB get together as surface mount gadgets or less as often as possible now as leaded parts.

2. EEPROM: This is an Electrically Erasable Programmable Read-Only Memory. Information can be kept in touch with these semiconductor gadgets and it tends to be eradicated utilizing an electrical voltage. This is normally applied to a delete nail to the chip. Like different kinds of PROM, EEPROM holds the substance of the memory in any event, when the force is killed. Likewise, as different kinds of ROM, EEPROM isn't as quick as RAM.

3. EPROM: This is an Erasable Programmable Read-Only Memory. These semiconductor gadgets can be modified and afterward eradicated sometime in the future. This is ordinarily accomplished by uncovering the semiconductor gadget itself to bright light. To empower this to occur there is a round window in the bundle of the EPROM to empower the light to arrive at the silicon of the gadget. At the point when the PROM is being used, this window is regularly secured by a name, particularly when the information may should be safeguarded for an all-inclusive period.

4. Flash memory: Flash memory might be considered as an improvement of EEPROM innovation. Information can be kept in touch with it and it tends to be eradicated, albeit just in blocks, yet information can be perused on an individual cell .

5. MRAM: This is Magneto-resistive RAM, or Magnetic RAM. It is a non-unpredictable RAM memory innovation that utilizes attractive charges to store information rather than electric charges. Not at all like advances including DRAM, which require a consistent progression of power to keep up the trustworthiness of the information, MRAM holds information in any event, when the force is eliminated. An extra bit of leeway is that it just requires low force for dynamic activity. Accordingly, this innovation could turn into a significant part in the hardware business since creation measures have been created to empower it to be delivered.

6. PROM: This represents Programmable Read-Only Memory. It is a semiconductor memory which can just have information kept in touch with it once - the information kept in touch with it is perpetual. These recollections are purchased in a clear arrangement and they are customized utilizing a unique developer.

7. SDRAM: Synchronous DRAM. This type of semiconductor memory can run at quicker speeds than traditional DRAM. It is synchronized to the clock of the processor and is equipped for keeping two arrangements of memory tends to open all the while. By moving information then again from one lot of addresses, and afterward the other, SDRAM eliminates the deferrals related with non-simultaneous RAM, which should close one location bank before opening the following.

8. SRAM: It implies Static Random-Access Memory. This type of semiconductor memory picks up its name from the way that, in contrast to DRAM, the information shouldn't be invigorated powerfully.

Significant of PCM:

Stage Change Memory is kind of non-unstable PC memory (NVRAM) that is now and again alluded to as "impeccable RAM" because of its boss presentation attributes. There are different huge that are related with Phase Change Memory in correlation with different kinds of memory stockpiling, including NAND Flash Memory.

PCM offers the guarantee of compose cycles that could be fundamentally quicker than NAND streak. NAND Flash expects information to be deleted before new information is composed, while PCM has no such prerequisite, making it extensively quicker.

Examination has discovered that entrance times under 5 µs can be accomplished with PCM. Given that PCM doesn't have to eradicate information first, sellers and scientists have assessed that Phase Change Memory can deal with more compose cycles than NAND streak.

PCM offers the guarantee of lower power necessities than its NAND partners. A one of a kind trait of Phase Change Memory is that it will have the option to both execute code, much like existing DRAM, just as can store information like NAND.

Challenges in PCM:

Stage change memory (PCM) is a type of PC irregular access memory (RAM) that stores information by adjusting the condition of the issue from which the gadget is manufactured. As indicated by its defenders, PCM innovation can possibly give cheap, rapid, high-thickness, high-volume nonvolatile capacity on a remarkable scale. There are numerous difficulties for the Phase Change Memory.

The main test is particularly for rapid PCM, which is the activity speed. For the most part, as the film goes slenderer, the crystallization speed drops and stage change temperature increments. Warm conditions that consider quick crystallization ought not be excessively like backup conditions, for example room temperature. In any case information maintenance can't be continued. With the correct enactment vitality for crystallization it is conceivable to have quick crystallization at programming conditions while having extremely moderate crystallization at typical conditions. That is the reason immaculate material is required which can arrive at quicker to the glasslike condition. The PCM stockpiling component comprises of two terminals isolated by a resistive radiator and a chalcogenide (the stage change material). Ge2Sb2Te5 (GST) is the most generally utilized chalcogenide, yet others offer higher resistivity and improve the gadget's electrical attributes. Nitrogen doping builds resistivity and brings down programming current, while GS offers lower dormancy stage changes.

Presumably the greatest test for stage change memory is its drawn out obstruction and limit voltage float. The opposition of the formless state gradually expands as indicated by a force law (~t0.1). This seriously restricts the capacity for staggered activity (a lower moderate state would be mistaken for a higher halfway state sometime in the future) and could likewise endanger standard two-state activity if the edge voltage increments past the plan esteem.

The best test for stage change memory has been the prerequisite of high programming current thickness (>107 A/cm², contrasted with 105...106 A/cm² for a regular semiconductor or diode). The contact between the hot stage change area and the adjoining dielectric is another major concern. The dielectric may start to release flow at higher temperature, or may lose bond while extending at an alternate rate from the stage change material. PCM cells are one-semiconductor (1T), one resistor (1R) gadgets containing a resistive stockpiling component and an entrance semiconductor. One of three gadgets ordinarily control access: a field-impact semiconductor (FET), a bipolar intersection semiconductor (BJT), or a diode. Later on, FET scaling and huge voltage drops over the cell will unfavorably influence entryway oxide dependability for unselected word lines. BJTs are quicker and can scale all the more heartily without this weakness. Diodes possess littler territories and possibly empower more noteworthy cell densities yet require higher working voltages.

cathodes isolated by a resistive warmer and a chalcogenide (the stage change material). Ge2Sb2Te5 (GST) is the most generally utilized chalcogenide, yet others offer higher resistivity and improve the gadget's electrical qualities. Nitrogen doping builds resistivity and brings down programming current, while GS offers lower idleness stage changes. (GS contains the initial two components of GST, germanium and antimony, and does exclude tellurium.) Likely the greatest test for stage change memory is its drawn out obstruction and limit voltage float. The opposition of the nebulous state gradually builds as per a force law (~t0.1). This seriously restricts the capacity for staggered activity (a lower moderate state would be mistaken for a higher transitional state sometime in the future) and could likewise imperil standard two-state activity if the edge voltage increments past the plan esteem.

The best test for stage change memory has been the necessity of high programming current thickness (>107 A/cm², contrasted with 105...106 A/cm² for a run of the mill semiconductor or diode). The contact between the hot stage change district and the adjoining dielectric is another key concern. The dielectric may start to release flow at higher temperature, or may lose bond while extending at an alternate rate from the stage change material. PCM cells are one-semiconductor (1T), one resistor (1R) gadgets involving a resistive stockpiling component and an entrance semiconductor. One of three gadgets normally control access: a field-impact semiconductor (FET), a bipolar intersection semiconductor (BJT), or a diode. Later on, FET scaling and enormous voltage drops over the cell will unfavorably influence door oxide dependability for unselected word lines. BJTs are quicker and can scale all the more heartily without this weakness. Diodes involve littler territories and possibly empower more noteworthy cell densities however require higher working voltages.

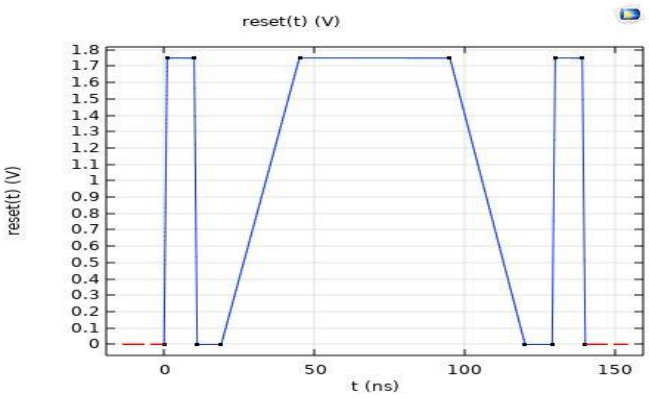
COMSOL Multiphysics is a cross stage limited component investigation, solver and Multiphysics recreation programming.

In midterm we have recently presented with the COMSOL. we realized that how it functions in PCM yet we didn't any reproduction by utilizing this product for PCM. Be that as it may, we learned about Heat Transfer module which is utilized for Analyzing heat move by conduction, convection, and radiation. In definite term we have utilized COMSOL. recreation programming for PCM furthermore, we did a reenactment by utilizing this product. We have utilized GST, TIN and Silicon dioxide as a component to plan a cell of PCM.

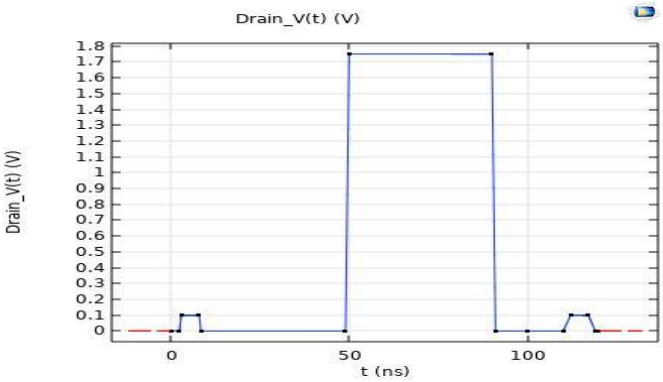
Also, this reenactment manages a mathematical examination of the dissolving cycle of a PCM in rectangular fenced in area differentially warmed. COMSOL Multiphysics is utilized so as to mathematically understand Naiver-Stokes and vitality inquiries in the thought about framework. Furthermore, this condition is utilized to illuminate transient conduction and convection heat move in both strong and fluid stage.

II. METHODOLOGY:

At first the Multiphysics were placed in COMSOL for 2D. We had to create silicon Si, Si02, GST and TiN and place the different properties for each of the materials. For each material thermal conductivity, density, heat capacity at constant pressure, electrical conductivity, resistive permittivity and seebeck coefficient were different from each other. We selected two pulses for Definition which are drain and reset pulse.



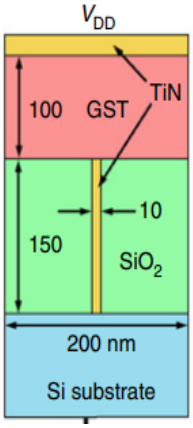
Reset Pulse



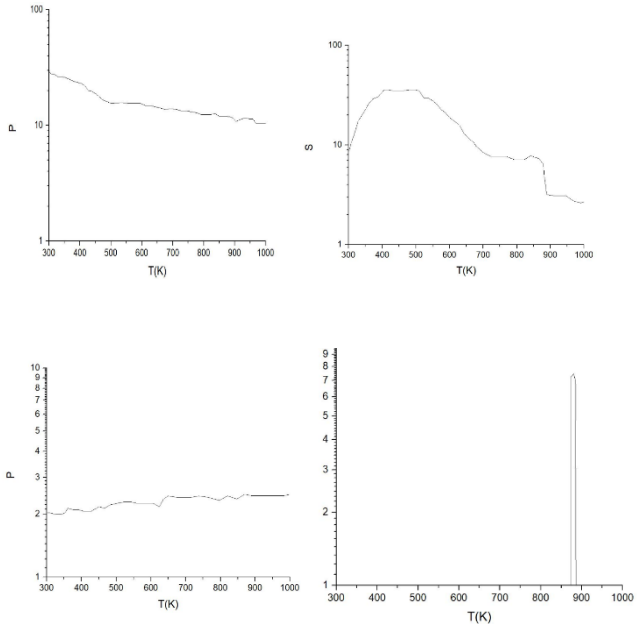
Drain pulse

Then we selected geometry and selected length unit in nm. After that selected a rectangle for defining Si and set the width 85nm, height 50nm, selected base in the corner and

r=0. Then for TiN we selected another rectangle and set width =5, height 99, r=0, z=50. Then Electrode (TiN). After that we created a polygon for SiO2 and made a vector created a polygon for SiO2 and made a vector r= [85 5 85
85], Z= [50 50 150 150 150] .



The reenactment was finished by COMSOL programming and the estimations of the materials were separated from the ORIGIN programming. From the start the materials were set in COMSOL. We needed to make silicon Si, Si02, GST and TiN and spot the various properties for every one of the materials. For every material warm conductivity, thickness, heat limit at steady weight, electrical conductivity, resistive permittivity and seebeck coefficient were unique in relation to one another. Initially, we needed to make Si at the clear square and the shade of the square changes from red to blue. Silicon esteems will show in the essential. For putting the TiN we needed to go on the fundamental and afterward select capacities and after that addition and furthermore level that as TiN sigma and select information source as result table and after that we needed to choose starting point estimation of TiN signal.



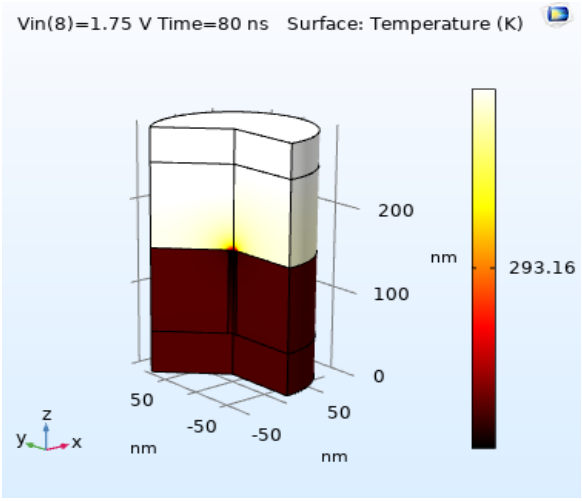
Extracted graph from Origin

Same methodology was followed for TiN_K and TiN_seebeck and inception esteems were set to make the materials.
For cause esteems, from the start a preview of the chart which is given in report was taken, at that point open the snap short in birthplace lab. At that point we select all the conceivable point in the snap short and concentrate information from the source table to a txt record.
yet, in the conductivity case we alter the information through python code at that point include that information in another txt document and joined them in COMSOL recreation.
For setting GST we needed to go to the materials, at that point select clear, after that level this as GST and spot the condition that were utilized for material substance

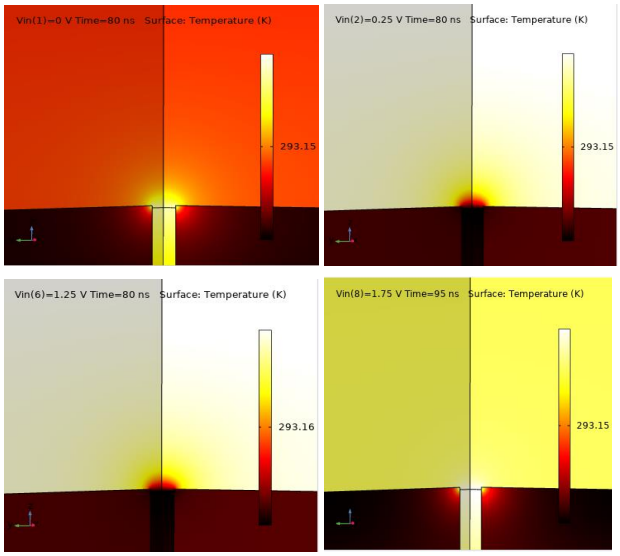
After that we need to go fundamental at that point capacities, after that insertion and afterward level GST and select information source from root table. After that equivalent system were followed for GST (K) , CP ,C_GST_sigma, a_GST_Sigma, c_seebeck, a_seebeck and addition.
Presently from electrical flow two terminals were put. These terminals would associate with TiN (terminal 1) and +VDD (at terminal 2) . At terminal 2, terminal sort was chosen as circuit.
For terminal one we needed to tap on the limit which naturally select 9 areas and for terminal 2 number 4 space were chosen.
ODEs and DAEs module have two of course area dissemination ODE 1 and introductory qualities 1.
In Multiphysics module both thermoelectric impact 1(tee1) also, electro painting warming 1(emh1) are choice are naturally no determination are required.
At that point in work area size at that point adjust for chose to general material science and prefunded set to typical for normal execution.
At last, at study area parametric range are included and this area Vin run (0,0.25,1.75) are included. At that point stage 1: time subordinate range are set to extend (0,5,100). At that point register the reproduction for result.

II. RESULT:

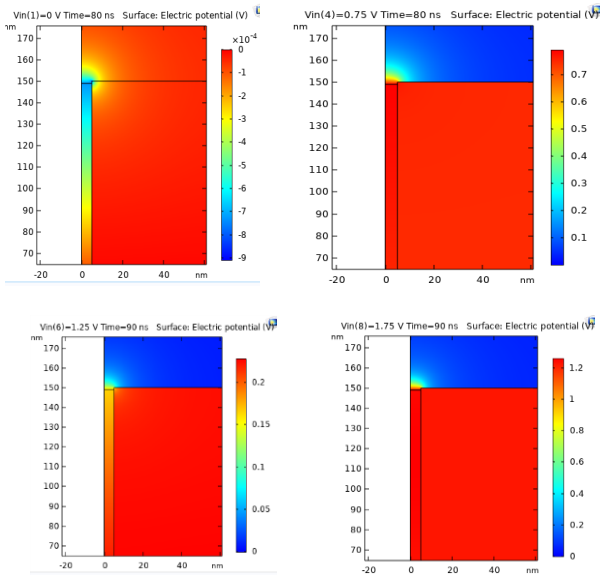
Thermoelectric warmth and flow in the PCM cell result in an essentially adjusted temperature circulation close to the dynamic district. As we did getting our normal outcome in reset activity on a Ge2Sb2Te5 (GST) mushroom cell therefor we utilize a warm and electric protection among Tin and SiO2 also as among SiO2 and GST mushroom sell then we are getting our normal outcome. At the point when arranged in the negative extremity, the cell requires more current to effectively reset.
Thomson heat increments with expanding Seebeck inclination. Because of the sharp drop in Seebeck coefficient at softening the locale encompassing the liquid GST encounters the best Thomson impact; current heading decides if this impact warms or cools the locale, with positive and negative polarities including or eliminating heat, individually. Positive extremity reset activity brings about more grounded temperature inclinations for every current level.



Temperature 3D



Different temperature response in different time



Different electrical Potential for different voltage

IV. CONCULTION

Initially our aim was to study and learn about CONSOL software and to discover the thermoelectric effects in PCM through 2-D rotationally symmetric finite-element simulations of reset operation on a GST (Ge2Sb2Te5) mushroom cell with 10 nm critical dimension. At the starting of the semester the impacts of thermoelectric Thomson and Peltier effects on a mushroom PCM device was studied. But in the mid-term there was no simulation part using CONSOL software. So, in the final-term after studying the paper different simulation was done using CONSOL software. During simulation firstly Si material was used by following some instructions. Then similarly SiO2, GST and TiN material was used by following the instructions as well. There were some temperature-dependent material parameters (thermal conductivity of silicon, the heat capacity of constant pressure, electrical conductivity, relative permittivity and See beck coefficient) used, as well as an internal circuit model to include a MOSFET as an access device. Both cell polarities have been simulated using 100-ns reset pulses resulting in thermoelectric heating or cooling within the GST active region and TiN heater and at the GST/TiN interface. However, after computing the simulation, the exact desired result was not found. By changing the range of voltage and time the expected color was found, which denotes the temperature ranges. By analyzing these results, PCM with greater effective cells can be achieved with constructions and operation polarity that maximize thermoelectric warmness in the active region.

V. REFERANCE:

1.Wong, H.-P., Raoux, S., Kim, S.B., Liang, J., Reifenberg, J.P.,
Rajendran, B., Asheghi, M., and Goodson, K.E.: 'Phase change
memory', Proc. IEEE, 2010, 98, pp. 2201–2227
2. COMSOL: 'COMSOL Multiphysics® 4.2a', 2008

3. Faraclas, A., Bakan, G., Williams, N., Gokirmak, A., and Silva, H.:
'Thermoelectric effects in phase-change memory cells'. Material
Research Society Spring Meeting, 2013, Vol. H1.03

4. Faraclas, A., Williams, N., Gokirmak, A., and Silva, H.: 'Modeling of set
and reset operations of phase-change memory cells', IEEE Electron
Device Lett., 2011, 32, pp. 1737–1739-3

5. Fischer, S., Williams, N.E., Osorio, C., Ayas, S., Silva, H., and
Gokirmak, A.: 'Percolation transport and filament formation in nanocrystalline silicon nanowires', J. Appl. Phys., 2013, 113, p. 164902

6. Kan'an, N., Faraclas, A., Williams, N., Silva, H., and Gokirmak, A.:
'Computational analysis of rupture-oxide phase-change memory cells',
IEEE Trans. Electron Devices, 2013, 60, pp. 1649–1655

7. Bakan, G., Cywar, A., Silva, H., and Gokirmak, A.:
'Melting and crystallization of nanocrystalline silicon microwires through rapid self-heating',
Appl. Phys. Lett., 2009, 94, pp. 251910–251910-3

Contribution of Group mates in report writing:

Serial	Name	ID	Contribution
1.	Das,Sourav	18-37400-1	Result
2.	ABDULLAH AL NOMAN	17-34751-2	Conclusion
3.	Moon Tansir Mamun	18-37315-1	INTRODUCTION
4.	Faizul Karim Polash	18-36315-1	METHODOLOGY
5.	MAHMUDUL HASSAN	18-37380-1	REFERANCE
6.	REDWAN ISLAM	17-35146-2	METHODOLOGY