Deposition of Copper and Aluminium Thin Films on Glass and Silicon Wafer Substrates in Particle Controlled BAEC Clean Room

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***Abstract*—One VLSI laboratory has been established at Institute of Electronics (IE) of Atomic Energy Research Establishment (AERE) which is the only one in Bangladesh in electronics fields. This laboratory consists of one 1000 grade yellow room and two 10000 grade white room which satisfies the federal standard 209E. There are many VLSI machinery have been installed inside the clean room which are classified in three categories. The 4-probe station (type: EP6), Film thickness monitor (model: SR-2), Optical microscope, Surface profilometer are used for sample characterization. For processing purpose many machinery are used such as LPCVD (model: LC 100), PECVD (model: SI500PPD), RIE (model: NRE-4000), Mask Aligner (model: MJB4), RTP, UV exposure unit, Mini coater, Spinner, Ultrasonic bath, Hot plate, De-ionized water plant, Dry nitrogen jet gun, Lapping machine etc. Die bonder and Wire bonder are used for packaging and encapsulation purposes. There is one particle counter measures the dust particles inside the clean room. This paper will describe the condition and operation of clean rooms that have been established inside the VLSI laboratory at IE, AERE. The contents of this paper also describe the results of the latest research and standardization works together with applications in both industry and research and development laboratories in our country.**

***Keywords*—deposition; thin films; wafer; clean room.**

I. INTRODUCTION

The demand of Experienced and skilled man power in the field of Electronics Technology is increasing day by day. But, Bangladesh is far behind from the modern technique used in the field all over the world. To go with the world and achieve the most modern technology this laboratory can be assumed as the incipient step and can play a pioneer role in Bangladesh. Very Large Scale Integration (VLSI) has become the basis of modern electronic technology. The objective of VLSI is to insert millions of electronic components and hundreds of circuits into a single chip. There are mainly three steps involve in VLSI technology i.e. VLSI design, IC fabrication and manufacturing of IC chip. Bangladesh Atomic Energy Commission has been established a centre of excellence for the Development of VLSI (Very Large Scale Integration) Technology in the country. The rudimentary step comprises to establish such a laboratory, a Clean Room of high purity and precision. In a simple word, clean room is a room that is clean. Basically, a clean room is a room which mainly contains clean environment i.e. concentration of airborne particles is controlled inside the room and which contains one or more clean zones. In addition, the relative factors such as humidity, temperature, air pressure, air flow patterns, vibration, noise, lighting etc. should be controlled to specified limits. According to the Federal Standard 209E, it defines a clean room as a room in which the concentration of air borne particles is controlled to specified limits. Clean rooms are classified by the cleanliness of air. Standards are very important in designing process. Clean room specifications for particulate matter (such as dust) are defined according to the maximum allowable particle size and also according to the maximum allowable number of particles per unit volume. In Atomic Energy Research Establishment, The centre of excellence exhibits two white rooms of 10,000 grades and one yellow room of 1000 grade cleanliness. According to the Federal Standard, a Class 1000 clean room is defined as a room would not contain more than 1000 particles bigger than 0.5 micron in a cubic foot of air. Similarly, a class 10000 clean room is defined as a room would not contain more than 10000 particles bigger than 0.5 micron in a cubic foot of air. In VLSI and ULSI technology, it is more important to prevent airborne particles and contamination. Clean room provides the environment necessary to manufacture and assemble of these devices. To implement the project successfully it was executed into two phases. The first phase includes designing of VLSI, development of a standard Clean Room and set up of required equipment and the second phase includes fabrication of IC chip. The main objective of this project is to set up a low cost VLSI design laboratory in Bangladesh. However, it will also cover the factors that are the Introduction of a very important, most modern and sophisticate technology in the country. Apply the developed technology for the industrial and economic development of the country.

II. METHODOLOGY

The Institute of Electronics (IE) in Atomic Energy Research Establishment (AERE), has been established a Centre of Excellence for the development of VLSI technology which is the first and only one Established laboratory in Bangladesh for VLSI technology. The Centre of Excellence consists of a clean room inside the area. This clean room is divided into twelve individual clean areas. These clean areas are classified by the cleanliness of air according to the Federal standard 209E. Rooms are divided into the following classes:

- **<u>Grade 100000:</u>** Primary change room, Intermediate room 1 & 2, Store, Washing room, Change room(ISO 8).
- **<u>Grade 10000:</u>** Airlock, Room 1 & Room 2 White room.(ISO 7).
- **<u>Grade 1000:</u>** Airlock yellow, Room 3 yellow room.(ISO 6).
- **<u>Grade no class:</u>** Corridor.

According to the various standardization the recommended temperature for clean room in semiconductor industry is 22˚C ± 2˚C; the pressure difference between two clean zones varies from 0 Pa to 50 Pa according to the room classification and the relative humidity which deals a great concern in clean room is recommended between 45% to 50%. For the fulfillment of these criteria, HVAC (Heating, Ventilation and Air Conditioning) systems are installed in the technical area on the ground floor (Air Handling Units) or outdoors (Chiller) in the Atomic Energy Research Establishment. The Air Handling Units both play an important role to control the Clean Room operation by controlling the number of air borne particle, temperature, humidity and positive differential pressure. Several times measured the room cleanliness by using the CI-453 particle counter and the measuring results are given below by Fig. 1 and Table I .

TABLE I. Measuring result for grade 100000 clean areas.

Area	**Sample Location**	**Particles / Cubic feet**
		0.5 µm & above
Room: 001	1	5200
Primary change room	2	5090
Room: 002	1	3055
Intermediate room 1	2	2250
Room: 003	1	5430
Intermediate room 2	2	4930
Room: 004	1	5305
Store room	2	5255
Room: 005	1	2145
Washing room	2	1770
Room: 006	1	5870
Change room	2	5645

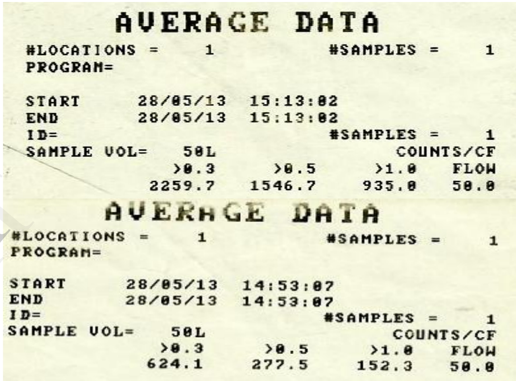

Fig. 1. Result for class 10000 and 1000 clean areas.

The cleanliness of grade 10,000 and grade 1000 clean areas has been monitored continuously for one week. The measuring results are given below in the Table II.

TABLE II. One Week monitoring reports from the particle counter on grade 10,000 & 1000 Clean areas.

Serial Number	**Grade 10000 Clean Areas**	**Grade 1000 Clean Areas**
	0.5 µm & above	***0.5 µm & above***
1st Day	3133.5	587.3
2nd Day	2894.7	531.8
3rd Day	3006.3	557.2
4th Day	2585.1	467.7
5Th Day	2167.6	403.5
6th Day	1672.2	336.6
7th Day	1546.7	277.5

From the above table, it can be quickly evaluated that there is a main difference in the amount of particulates in the rooms between testing on 1st day and testing on 7th day. From the table it can be seen that the number of air borne particles decreases day by day. So if we will maintain the proper guidelines, then the clean room will be run successfully. From the above results, we can find that the standard of the clean areas inside the Center of Excellence are very much satisfied according to both Federal and ISO standard.

*Temperature, Differential Pressure & Humidity Measurement:*The measurement is being done on the room temperature; relative humidity and positive pressure difference by using the "Dewk" Thermo-Hygrometer during the Air Handling Units are running. The measuring values are given below Table III.

TABLE III. Measuring values of different parameters.

Room	**Description**	**Air Changes/ Hour**	**Classification**	**Differential Pressure (Pa)**	**Temperature**	**Humidity**
001	Primary Change room	> 17	100000	15	23˚C	< 55%
002	Intermediate room 1	>17	100000	10	23˚C	< 55%
003	Intermediate room 2	>17	100000	0	23˚C	< 55%
004	Store	>17	100000	10	23˚C	< 55%
005	Washing room	>17	100000	0	23˚C	< 55%
006	Change room	>17	100000	10	23˚C	< 55%
007	Airlock	>40	10000	0	23˚C	< 55%
008	Room 1 White Room	>40	10000	15	23˚C	< 55%
009	Room 2 White Room	>40	10000	25	23˚C	< 55%
010	Airlock Yellow Room	>50	1000	40	23˚C	< 55%
011	Room 3 Yellow Room	>50	1000	50	23˚C	< 55%
012	Corridor	>17	N/A	N/A	23˚C	< 55%

From the above results, the temperature and differential pressure of the clean areas inside the Centre of Excellence are very much satisfied according to the international standards but the relative humidity is slightly more than the expected value. This humidity can be easily controlled by operating Air Handling Unit for long periods with maintaining the recommended value of the parameters of the Air Handling Unit. For more precaution, 10 De-Humidifiers are used when the clean rooms are in fully operational state. So we can able to control the relative humidity around 45% or less.

III. RESULT AND ANALYSIS

Last one year, the environment of the Centre of Excellence had been suitable for research work and many research works and characterizations were done successfully on thin film deposition.

Recently a research work has been done by using Copper (Cu) and Aluminium (Al) materials and these materials have been deposited on glass substrates as well as silicon wafers by using thermal evaporator. Then characterized the samples and measure the thickness of Cu and Al layer on glass substrates and silicon wafers with the help of the Stylus Surface Profilometer. This profilometer is used to measure the surface's profile in order to quantify its roughness.

The following Fig. 2. shows a part of the deposition of Copper surface on the glass substrate which has been measured by Dektak surface profilometer. For characterization and measurement of the thickness of Cu and Al layer, at first aligned the Reference Bar (R) such a way that it can indicate the actual surface of the wafer and Measuring Bar (M) is placed in such a way that we can measure approximately the length of Copper and Aluminium deposition on the substrates and silicon wafers. Fig. 2. have been got from Dektak Surface Profilometer in order to measure the thickness of Copper and Aluminium thin film on both the Glass Substrates and Silicon wafers.

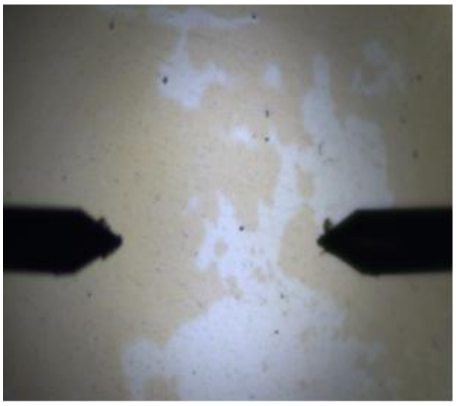

Fig. 2. Copper surface on Glass Substrate

The thin film of Copper on glass substrate is shown in Fig. 3 , 4 and 5. The thickness of thin films are 2000 A^{0}, 2200 A^{0}, 2500 A^{0}.

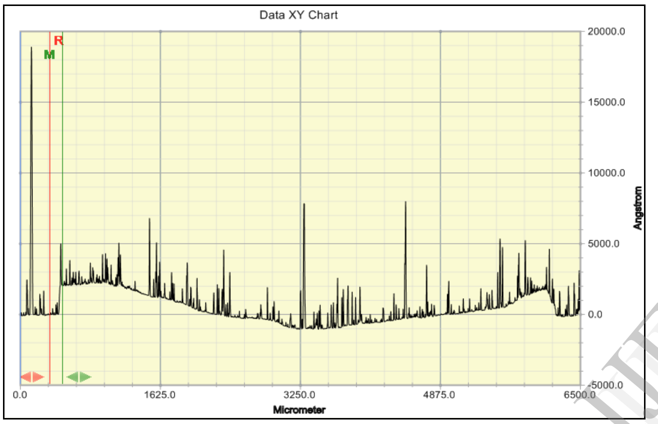

Fig. 3. Thin film of Copper on glass with thickness of 2000 A˚.

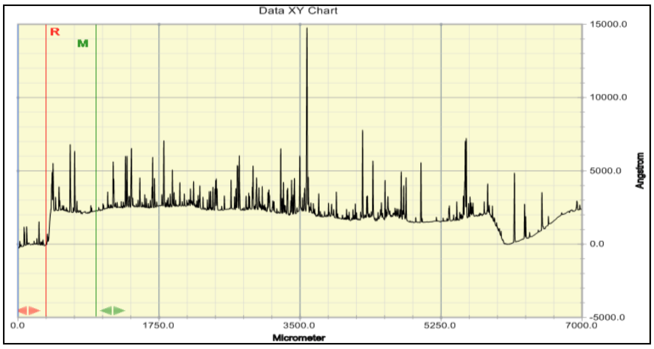

Fig. 4. Thin film of Copper on Glass with thickness of 2200 A˚

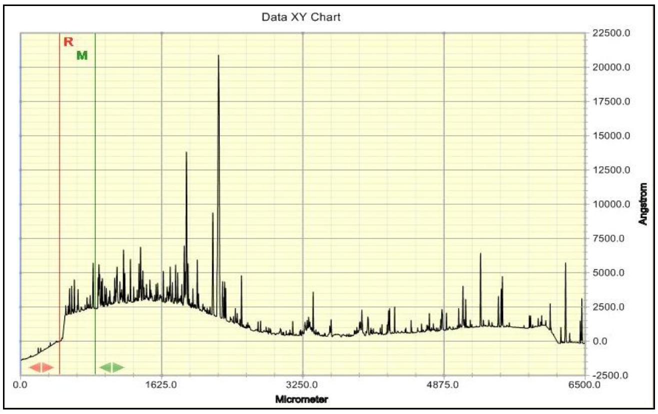

Fig. 5. Thin film of Copper on glass with thickness of 2500 A˚

The resulted value of the thickness of copper deposition on the glass substrate is given below in Table IV.

TABLE IV. Thickness of Copper on Glass Substrate.

Serial Number	**Measurement of Thin Film (Angstrom)**
1	2000
2	2500
3	2200

The thin film of Copper on silicon wafer is shown in Fig. 6 and 7.

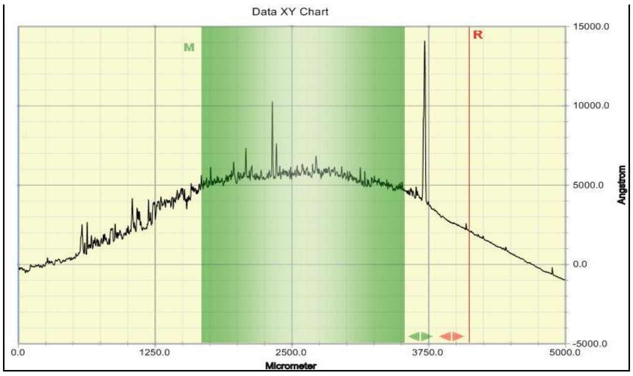

Fig. 6. Thin film of Copper on silicon wafer with thickness of 3500 A˚

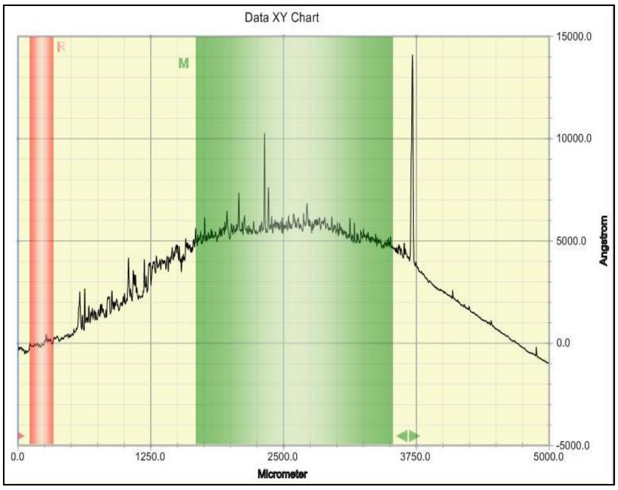

Fig. 7. Thin film of Copper on silicon wafer with thickness of 5500A˚

The resulted value of the thickness of Copper deposition on the silicon wafer is given below in Table V.

TABLE V. Thickness of Copper on Silicon Wafer.

Serial Number	**Measurement of Thin Film (Angstrom)**
1	3500
2	5500

The thin film of Aluminium on glass substrate is shown in Fig. 8, 9 and 10.

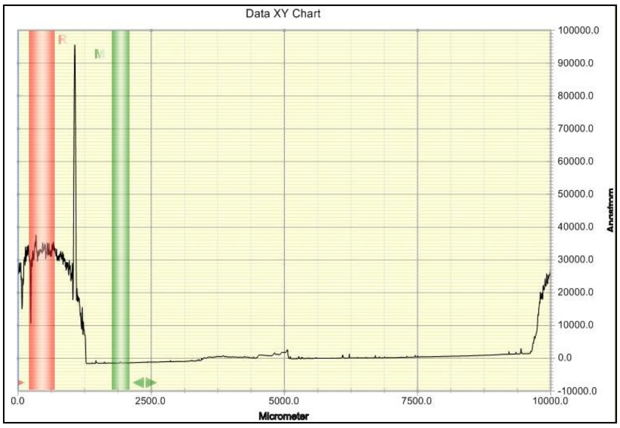

Fig. 8. Thin film of Aluminium on glass substrate of thickness 30,000A˚

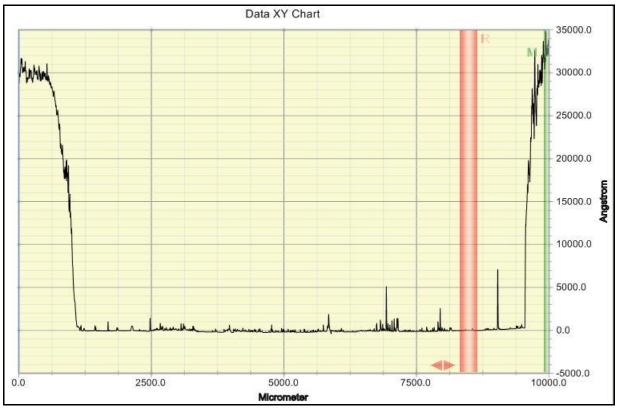

Fig. 9. Thin film of Aluminium on glass substrate of thickness 33,000A˚

Fig. 10.

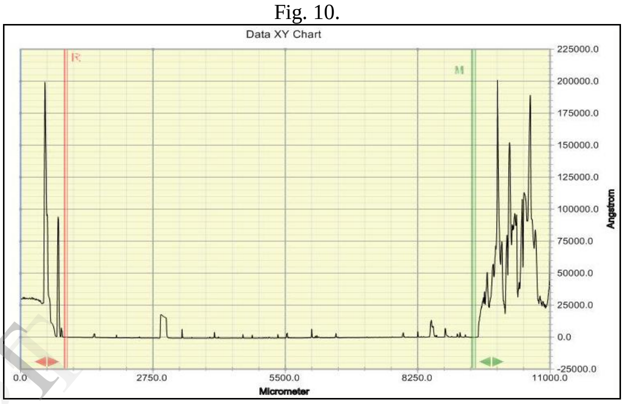

Fig. 11. Thin film of Aluminium on glass substrate of thickness 25,000A˚

The measured value of Aluminium deposition on the Glass Substrate is given below Table VI.

TABLE VI. Thickness of Aluminium on glass substrate.

Serial Number	**Measurement of Thin Film (Angstrom)**
1	30,000
2	33,000
3	25,000

The measured value of Aluminium deposition on the Silicon Wafer is given below Table VII.

TABLE VII. Thickness of Aluminium on silicon wafer.

Serial Number	**Measurement of Thin Film (Angstrom)**
1	30,000
2	33,000

The thin film of Aluminium on silicon wafer is shown in Fig. 11 and 12.

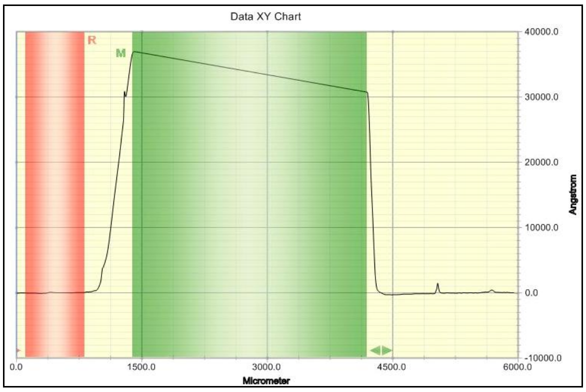

Fig. 11. Thin film of Aluminium on silicon wafer with thickness 37,000A˚

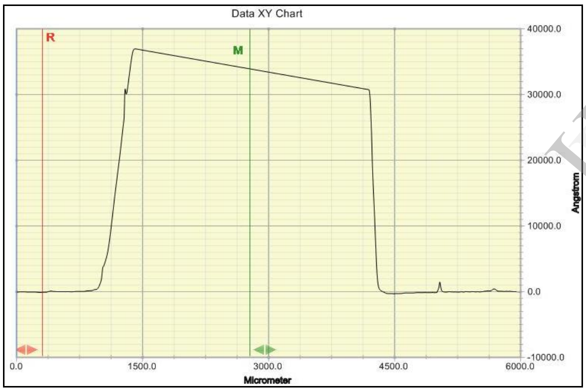

Fig. 12. Thin film of Aluminium on silicon wafer with thickness of 34,000A˚

The variation of comparison of Cu and Al is shown in the form of graphs in Fig. 13 and 14.

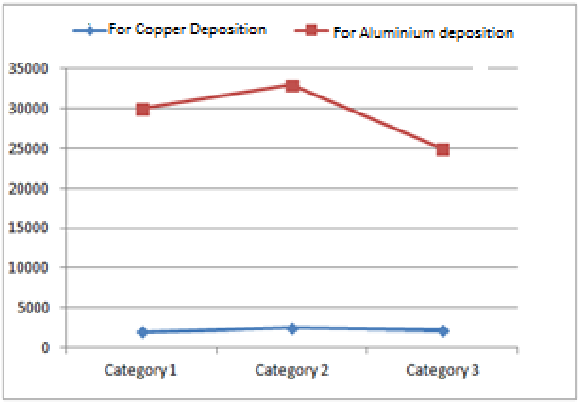

Fig. 13. Variation of Cu & Al deposition on glass.

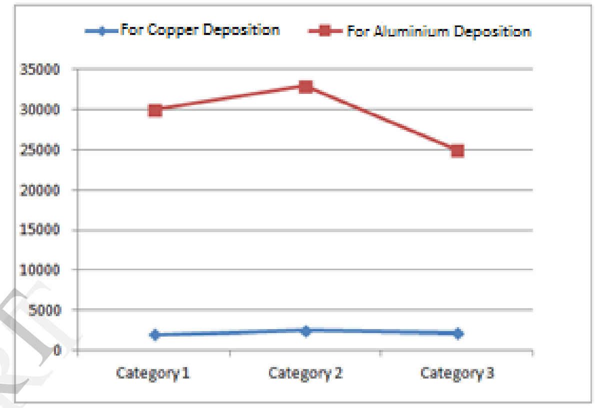

Fig. 14. Variation of Cu & Al deposition on silicon.

From the above figures, the result indicates that the thin film fabrications of Cu and Al on glass substrates and on silicon wafers are successfully done. From Thin Film deposition, the result has been got in Nano Scale. For Copper deposition, the values are 200-250nm on glass substrate & 350-550nm on silicon wafer and for Aluminium deposition, the values are 2500-3000nm on glass substrate & 3000-3300nm on silicon wafer. It is wise to say that this is a tremendous achievement for us and for our country. The Centre of Excellence followed every rules of modern Clean room technology and successfully installed a Grade 1000 and Grade 10000 clean room. The Centre of Excellence is now equipped with all necessary VLSI machinery and ready to do any fabrication works in micro and nano level with very precise tolerances.

IV. CONCLUSION

The Centre of Excellence is the first and only one established laboratory for the development of VLSI (Very Large Scale Integration) Technology and Micro fabrication sector in our country. Inside this laboratory, sometimes it is hard to keep the humidity constant but the rest of the things are easily controlled. Although, this research lab is very much new, but the clean room condition is very good for IC fabrication. The success of this laboratory may help our country to enter in a new era of technology. It will help to develop expertise and skilled manpower which will encourage the scientists and engineers in the country to research on VLSI. It will also help to develop and improve electronic industry in Bangladesh by creating job facilities for skilled people in the country. As the demands of VLSI designers are increasing day by day all over the world, Bangladesh can take apart to meet the demand and earn foreign currencies by exporting the VLSI designs or expertise thereby contributing to the economic development of the country.

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