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SEMI-CONDUCTOR AMBIENCE FOR BUILDING SELF-RELIANCE IN THE COUNTRY

Kamaljeet Singh and S.V. Sharma
Systems Engineering Group, ISRO Satellite Centre, Bangalore, India

Abstract

In the present era of importing chips are the major bottlenecks in attaining self-reliance for the strategic sector in the country. The existing trend of chip development at nanometer geometry needs huge and constant capital investment which is not possible in present scenario. The requirement of the country is to have maximum and efficiently utilization of available technology which can cater for achieving self-reliance in strategic sector requirements. Further effort towards miniaturization and multiple operations using single chip solution can put country on the world map. The major bottlenecks in the country are the fabrication and realization of such systems which can leads to self-reliance in the country. In spite of the whole hearted support of the government still we are far behind in achieving self-sufficiency with the available technology node. Some of the industries closed their manufacturing operations and remaining are not performing as per expectations. In spite of leaders in chip design and flooded with best talent still we are way behind self-reliance in the area of semiconductor in spite of huge investments. This article will bring out the foundry complexity, present scenario in the country, corrective methodology, and suggestive framework for creating semiconductor ambience in the country.

Keywords:

Semiconductor Industry, Self-Reliance, Technology Upgradation, Integrated Circuits

1. INTRODUCTION

The 21st century era is of electronics systems and semiconductor devices are the heart of these systems. The electronic industry is a billion dollar market worldwide and finds applications ranging from industrial, commercial, space, and defense. Semi-conductor demand in India is USD 10 billion and India's electronic consumption in 2020 could outstrip the demand of oil consumption as the design market in India is expected to increase by 29.4% to US$ 52.6 billion from US$14.5 billion in 2015. The integrated circuits penetrated in our daily lives such as cell phone, DTV, notebook, tablet, digital camera, LED [1]. Electronics consumption worth 37 billion dollar (58%) is imported by the country where major part is of semiconductor devices. Countries such as China and Taiwan are the hub of manufacturing with over 60% share in the world market but India is way behind as we are operating with fables foundries [2]. The FDI is also less than 2 billion dollar between 2000 and 2015. In spite of country having 120 companies for chip design, 20k chip designers and 2k chips being designed by the country but the manufacturing of the same is carried out in external foundry.

Present large number of companies are working in design but lacking fabrication facility in the country [1]. The design projects which they are handling have larger dependency on foreign FABs. Country strength in chip design is not commensuration in self-reliance as we are lacking in wafer fabrication. Local electronics manufacturing remains disconnected from India's chip design capabilities, research and development area [3]. In spite of country having 120 companies for chip design, 20k chip designers and 2k chips being designed by the country but the manufacturing of the same is carried out in external foundry.

India depends on imported integrated circuits (ICs) for its strategic sectors, even though some domestic chips have been used in missiles and satellites. Present era of dependency on foreign chips may compromise country's interest with possibility of breach of confidentiality. To overcome the imported consumption for strategic requirements, government initiated steps by establishment of fabrication units such as ITI, SCL and GAETEC in 80s. So far, India has been making chips fabricated by the Bharat Electronics, Gallium Arsenide Enabling Technology Centre in Hyderabad and the Semiconductor Complex Ltd (SCL) in Mohali for its space programme and defense. The GAETEC is a DRDO lab which provides GaAs chips for highly specialized communication applications in radio frequency. Basically silicon foundries is driving the growth of high end ASIC and FPGA which are prerequisite for creating high end circuits. The major scenario of fabs in India is as per Table.1.

Table.1. Indian foundries at present

Indian Fabs	Technology/node	Highlights
SSPL, Delhi	2"(50mm)	Cater to limited MEMS
CEERI, Pilani	4"/6"(100/150mm)	MEMS operations, CMOS as RandD
LEOS, Bangaluru	4" (100mm)	MEMS operations catering for space applications
IISc, Bangaluru	6" (150mm)	MEMS/NEMS
SCL, Mohali	6"/8" (150/200mm)	MEMS/CMOS operations (180 nm node)
Gaetec, Hyderabad	4" (100mm)	GaAs fab catering for microwave devices
BEL, Bangalore	4" (100mm)	Solar cell
STAR-C	6" (150mm)	MEMS operations only

As per Table.1, SCL foundry is having all the requisite infrastructure under one roof to cater for CMOS and MEMS operations having robust infrastructure and continual financial support. The SCL was set up in 1983 at a cost of $70 million with technology from American Microsystems Inc, Rockwell International and Hitachi. However, the company was wound down to a semiconductor laboratory although it continues to provide some chips for the strategic sector. As the NFIR (net foreign exchange inflow ratio) is negative, this indicates higher outflow of foreign exchange other than inflow so the foundry [4] was taken over by Department of Space in 2006 and converted into laboratory. It was upgraded with the technology node to 180nm so as to cater the requirements of strategic sectors which is fully operationalized in 2012-14 timeframe. The main objective of the present foundry is to cater the requirements of strategic sector and 180nm technology node is chosen to meet the present and future requirements of the country [5]. The evolution of the technology node is shown in Table.2.

Table.2. Evolution of technology node

Technology node	Year
10µm	1971
6µm	1974
3µm	1977
1.5µm	1982
1µm	1985
0.8µm	1989
0.6µm	1994
0.35µm	1995
0.25/0.21µm	1997
0.18µm	1999
14nm	2020

Compared to the overall import, the indigenous contribution presently from the fabs are miniscule. Earlier the focus was more on R and D to enhance technology that it acquired from abroad. This results in production taken back seat because the demand of SCL products is not sufficient to justify the financial investments in upgrading its foundries either due to lack of innovation or commitment for bringing out the products suited for indigenous applications.

The main reasons provided for equipment turn down time due to the import of the specialized part and absence of semiconductor environment in the country. As fabs around the globe are under private or public-private partnership which results in self-sustaining of the same. In India, in spite of financial support even 5% needs of the country are not catered for strategic sector. Indigenous foundry related with the silicon and GaAs are established 4 decades back with the emphasis on developing the niche technology. As GaAs caters for high frequency operations whereas silicon wafer is employed for IC processing which was initiated with the 5µm technology in ITI and SCL which progressively moved to 3, 1.2 and 0.8µm (Table.2) in SCL which is the only running full-fledged silicon fab catering for MEMS processing also. The present scenario of the existing foundry node of 180nm can cater the most of the requirements of the country and even can cater for commercial applications with the planned capacity.

This article details the macroscopic aspects of a running fab, nitty-gritty of operations, role of management, leadership qualities, and suggestive measures with management perspective in highly techno specified area.

2. SEMICONDUCTOR FABRICATION

Evolving of various technology node worldwide is listed in the Table.1. The below graph shows the ITRS roadmap viz-a-viz country scenario [source: VLSI research].

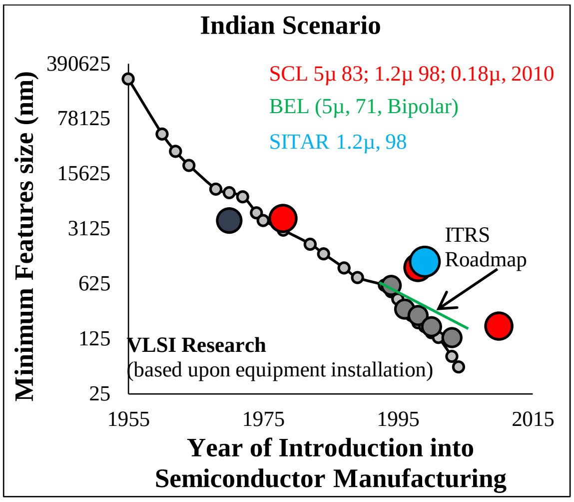

Fig.1. Technology node with the year of introduction

Chip manufacturing can be categorized into wafer, chip and product manufacturing. Front end of the line processes are active areas, well, soured-drain, salicide formations whereas back end of line processes are metallization, vias, interconnections and passivation. The major steps are shown in Table.3.

Table.3. Manufacturing process

Wafer manufacturing	Chip Manufacturing	Product Manufacturing
FEOL (front end of line)	Probe/Test	Packaging
BEOL (back end of line)	Singulation	Test

Any state of the art chip fabrication facility comprises of [6]

- Cleans Rooms
- Bulk gases
- Specialty gases
- Utilities Plants
- Distribution Networks operational on 24×7 basis

The utilities consist of ultra-pure water, electrical and thermal systems (acid, solvent, general exhaust) and waste management along with proper safety measures. The maintenance and upkeep of a facility result in highly reproducible results.

The upgradation of technology node results in differences which are: Gate Density, Core Clock, I/O Data Rate, Bit Cell Size (SRAM), Metal Layers.The processes upgraded are having various highlights which can be categorized as:

- Feature of baseline technology
- Process for Analog module
- Standard cell libraries

An example of two different nodes is taken and the basic differences between the nodes are shown in Table.4.

Table.4. Tentative technology node difference between geometry

Module	Higher technology node	Low geometry node
Well	Diffused Well Formation	Retrograde
Isolation	LOCOS	STI
Spacer	Oxide	Combination of Nitride and Oxide
Drain extension	Low doped (N+ only)	Doping Comparable to Drain
Contact	Silicide	Salicide (CoSiO2)
Contact/ via fill	Through sputtered Al	W plug
No of Metal	2	>2
Planarization	Etch back	CMP (chemical mechanical processing)
Passivation	Nitride	Low Stress Oxide/Nitride

There are specific processes such as: unit step process, short loop runs, engineering runs followed by product runs which are catered by various tools. The tool catering to these operations needs 24×7×365 operations to achieve reproducibility. Also critical aspects are the

- Tool uptime status
- Tools maintenance and calibration

A prerequisite for fab is to have standardized process and process development kit (PDK) to be created so as to be utilized by the designer.

Fabrication processes of CMOS and MEMS are mostly similar and MEMS is considered as the subset of the CMOS technology. Present demand of IoT is putting lot of emphasis on the sensors. MEMS technology in conjunction with CMOS technology is used to produce various sensors like Pressure, Temperature, Humidity, Accelerometers -for Automobile and Navigational systems, bio medical domain such as food calorie consumption and human health indicator, RF MEMS for communication Applications. [8]

All the basic fabrication steps which are derived from standard CMOS technology such as lithography, deposition, ion implantation are carried out in MEMS process apart from gold/Pt deposition and bonding mechanisms. Silicon is hard and elastic and process is repeatable, so sensors are reproducible in large volumes. Further the sensors penetrated a lot in commercial domain more so in automobiles sector. The challenges in this domain differ from CMOS are listed below:

- MEMS products are mostly patented encompassing processing, characterization, packaging and testing
- Difficult for single fab dealing simultaneously in production due to change in equipment parameters
- Lack of standardized process (product dependence)
- No single software for complete simulation study
- Non-existence of clarity related to packaging material, reliability testing etc.
- This technology needs maturity enough in the country to cater the demands as majority of the sensors are still imported.

Continual improvement of quality and reliability aspects is the important considerations. This can be achieved by having special attention on the yield improvement mechanism. The various reliability aspects at higher nodes are: electro migration, hot carrier injection, temperature instability, dielectric breakdown, stress, creep, crack etc. which needs specific attention. This requirement needs a strong team equipped with analytical ability to properly diagnose the problem.

3. VARIOUS ASPECTS FOR SEMI-CONDUCTOR AMBIENCE

The present scenario of semi-conductor fab in the country needs complete overhauling. The various impairments in this area are:

- Recurring breakdown of the tools
- Specific raw materials
- Expiry of raw material due to low volume
- Awaiting for raw material
- Disposable of Hazardous Waste
- Maintenance and upkeep
- Low yield
- Improper documentation and record
- Clarity and planning
- Guidance and team building effort
- Working environment
- Targeted goal towards self-reliance
- R and D activities and initiation of new developments
- Targeted programme in project mode

Lack of indigenization initiatives and repair expertise for tools, lackadaisical approach towards planning and implementation are the other factors which hinders the progress of semiconductor ambience in the country.

3.1 IMPROVEMENT APPROACHES

ISRO model is worth emulating and inspire many industries across the globe due to its unique ISRO culture [9]. The same to be followed which are briefed as below:

- Dissemination of knowledge and sharing attitude
- Openness resulting in free flow of ideas and accepting criticism in right spirit
- Team work and disciplined workforce
- Working environment
- Project based targeted approach
- Feasibility establishment

Transfer of knowledge to the young engineers results in the innovation and growth. The above stated aspects to be imbibed in the working culture which can results in overall organization growth.

3.2 MANAGEMENT ASPECTS

Important traits of an organization tasting continual success are:

- Committed and dedicated leadership (top down approach)
- Sound foundation and openness
- Calculated risk and taking responsibility
- Throwing new ideas and creating new challenges
- Keep setting new targets with roadmap

The individual should feel proud to be associated with the work and enthusiast enough to take up new assignments.

The role of leadership is of utmost important and its relevance is more so in semiconductor industry. The leader should earn respect by possessing the following qualities:

- In-depth knowledge of the subject or keenness in learning
- Highly dedicated with impeccable integrity
- Leading by example
- No self-centric approach
- Team building, involvement in activities
- Open for constructive criticism
- Principled stand
- Respecting others view
- Admitting mistakes
- Building and keeping trust
- Giving due credit and listening others perspectives

These traits are important for semiconductor industry due to job complexity; the role of leadership can make or mar the future of the organization. A leader should take proactive steps, lays foundation for future organization goal, create pool of young team and ready to give due credit. Further creating teams of yes man, self-centric approach, imposing and dictating mandate to committees, influencing the decisions are self-inflicted damages on the basic foundation of the organization and leader showing any such traits to be taken seriously. Promoting right people, impartial reviews and ratings , proper assignment, leading the team from the front, listening to the suggestions, taking strong decisions and provides proper direction are some other important factors which can turn around the outcome from industry .

3.3 WORK ENGAGEMENT

As per Schaufeli and Bakker [10] the work engagement are having three dimensions,

- Vigour
- Dedication
- Absorption

The engagement of the work force and imbibing the spirit that their ability to contribution is more and allowing to take calculated risks without punishing them for unsuccessful outcomes paves much more to the organization.

Motivational comes out in form of tangible or intangible reward given to the employee. The study shows that intangible reward such as praise and recognition plays much important role. Praise can be much effective as tangible rewards. Designing of the job profile making the job interesting and challenging which leader has to play a major role. Keeping the job simple and providing constant encouragement paves way for long term results.

3.4 SUGGESTIVE FRAMEWORK

The usage of developed products and integration with existing country's programme needs to be nurtured to get inducted into the main stream in time bound manner. A clear perspective of the activities in this area and road map for the same to be meticulously followed so as to enable the manpower meet the defined targets with constant enthusiasm. The bottlenecks to be taken one by one and ensuring remedial actions in time bound manner. Other requirements such as development of PDK, sharing of data, yield improvement, quality control, IP development and automation are to be taken parallel. Some of the suggestive actions are:

- Promoting sharing of resources and mid-course corrective actions
- Working Environment- technical guidance to be provided and innovative environment to be created
- Proper feasibility studies for any new activities
- Time bound completion of the projects

Other measures which need attention are:

- Breakdown/ Maintenance of the tools: data to be logged (proper documented) and easily accessible
- Automated mechanism to provide fab update/ recipe improvement/process variations to the designer regularly
- Calibration of the tools and ensuring its implementation with proper checklist
- Close coordination with indigenous fab SITAR/LEOS/IISc/CEERI/SCL to minimize fab downtime
- Process documentation, qualification procedures, Unit steps implementation, Inventory control FA analysis and detail report-action items to be generated and closed in time bound manner
- A high level committee to look into progress and regularly monitor -technical consultancy can be taken
- Involvement of designers, packaging, experienced engineers with sharing of knowledge, team formation catering for specific product range along with quality aspects.
- Reliability and quality aspects to be looked into
- Qualification of tool/procedures implementation and its certification preferably ISO standard
- Batch movement through intranet to all concern, daily progress monitoring
- Audit of the fab /utilities and its working with relevant technical manpower

Generally all fabs in India are working in isolation without sharing resources. The spares and gases commonly utilized can be pooled as semiconductor is resource hungry as shown in Fig.2.

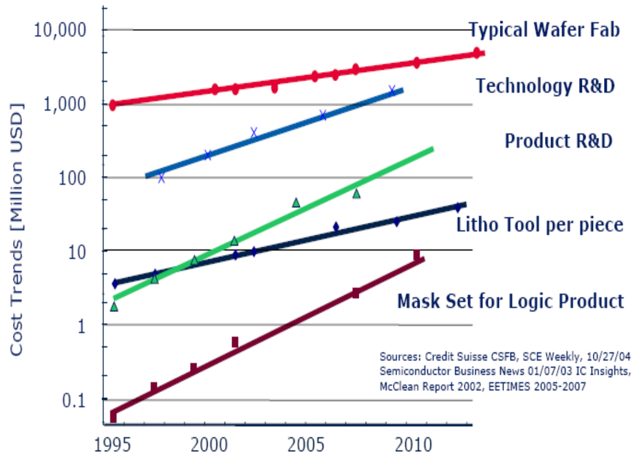

Fig.2. Cost trends for various processes

Source: Credit Suisse CSB, SCE Weely, 10/27/04 Semiconductor Business News 01/07/03 IC Insights, Mc Clean Report 2002, EETIMES 2005-2007

Some of the points which needs paradigm shift in the policy is:

- Shifting focus towards existing technology nodes (180nm) with 200mm wafer processing
- Evolving supply chain management and strong ecosystem [11]
- Focussed skill development
- IP creation and innovation
- Strong R and D environment engaging academia [7]
- Indigenization of parts, raw materials, equipment

A focused approach with professionally managed board can overhaul and can bring self-reliance in the country.

4. CONCLUSION

This article analyzes the present scenario and suggest the methodology so as to make the country self-reliant and world leader in this niche area of technology. Present scenario reflects gloomy picture where even for small development and modifications external help is sought. This compromises our design and development effort which needs immediate attention. Also it results in the bunch of unproductive manpower and taking back the progress. Immediate long term planning and strong review mechanism is needed.

Proper demarcation of work and close coordination between divisions to be ensured as it involves multiple agencies before final product delivery. Further ISRO culture and review mechanism to be adopted and suggestions to be timely implemented. Encouraging technical manpower to be involved both in projects as well as in research activities so as to carry out need based development.

Instead of creating duplication of resources and multiplication of the activities, a concentrated approach is needed to achieve the desired results. A consortium may be thought where resources (manpower and equipment) to be optimally utilized keeping country interest as supreme. This calls for winding of operations and consolidation of the same at one place like other major fabs across world. Further both strategic and limited commercial domain may be taken up to self-sustain the fab. Solar energy is the future of country which India is also pursuing. Solar cells need a semiconductor fab to meet the commercial and strategic demands of the country. The fabs working in isolation should join the pool so that expertise can be shared.

FDI to be encouraged in this sector and moreover the Maruti model of public private partnership can be adopted in this sector also. The reason for breaching confidentiality is not valid as in present scenario also the fab is running with the support of external contract.

Pumping money without involving and building human resource is dangerous for the organization. The same can be judged with the outlook of working manpower. The gloomy face with long unproductive discussions and indulging in passing time needs surgical intervention.

For a robust defense set-up, India ideally needs to have critical systems that are entirely designed and fabricated in India especially with regard to our military and space-related equipment. In spite of creating necessary infrastructure and taking turnkey solutions still the country is not benefitted and struggling to meet 1% of the requirements. The goal of self-reliance and self-sufficiency envisaged by converting complex to laboratory is yet to fructify as chips needed for space industry is still being imported which is around 20% of overall import of space projects. This not only strain the precious foreign exchange but put restraint to the critical development carried out in the country as India electronic market is soon going to be doubled. In 2012, India unveiled a new semiconductor policy aimed at encouraging the setting up of manufacturing units within the country. Department of electronics and information technology (DeitY) is dedicated to oversee the electronics growth in the country and presently emphasis laid for the manufacturing hub in this direction. Procedures and processes facilitate if earnest effort is carried out with proper planning. Some of the suggestive methodologies are:

- Easy access as labs are segregated and no target defined. Lesson learnt from failures to be incorporated
- Encourage students in microelectronics, basic sciences and discourage them to divert their skills in IT/BPO
- Practical oriented approach relevant to industry in curriculum. Bookish knowledge to be diverted to industry oriented courses
- Indigenous goods and industry protection from government by giving soaps like tax benefits etc.
- MNC's based in country to take only indigenous goods and put some money in R and D
- Relaxed norms and fast clearance for semiconductor units related with pollution, safety etc.
- Autonomy in these industry related to hiring suitable manpower, facilities etc.
- Intellectual property (IP) protection and creating an environment for the creation of the same
- Quality of product and assembly, packaging under one roof to be encouraged.
- Basic maintenance and upkeep of instruments- fast import clearance and less paper work to reduce breakdown time

- Utilizing fab capability by targeting exports/avenues of selling goods to new avenues/countries to have mass production, creation of export zones
- Discourage as far as possible the imported items-only case of deemed necessity
- Building long term feasible goals
- Semi-Conductor fabs (Si and GaAs) under one umbrella and efficient utilization of available resources

The semiconductor products are having both economic and strategic objectives. Apart from national security other sectors such as consumer electronics, automation and telecom products are utilizing the same and achieving self-reliance will reduce import bills. Indian chip design industry is taken over by renowned semiconductor industry of US, Singapore and France etc. Indian manufacturing industry can wholly cater this demand in all aspects of intelligence, man-power, raw material, natural resources and having great potential to evolve as a semiconductor manufacturing hub with right policies.

In authors view the aspects dealt in this article can help in creating semi-conductor environment in the country and paves Make in India for building of self-reliance in the country.

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