Semiconductor Industry & India's Possibilities

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Abstract **- The journey of development of semiconductors following Moor's law is a fascinating topic over past few decades which forms the basis of semiconductor industry globally. But participation of India in this development is not at all encouraging. In this work main focus is projected on the current status of India's semiconductor industry, related issues and hurdles, the possibilities and the future projects with government intervention.**

Keywords**: Moor's Law; Semiconductor Industry; Projects in India; Government Intervention**

I. INTRODUCTION

Semiconductor is one such element that works between Conductor & Insulator so far as conductivity is concerned. There are primarily two different types of semiconductors, the intrinsic semiconductor and the extrinsic. Silicon and Germanium are examples of intrinsic semiconductors and various impurity (Group III/ V elements of the periodic table) /doped semiconductors (Group IV) fall under the category of extrinsic type. Semiconductors are developed at a much faster rate in present days since its innovation [1]. In this context it may be mentioned that Gordon Moore's prediction regarding the development and growth of semiconductor is ultimately turned into famous Moore's Law, which states that the number of transistors used per square inch in the Integrated Circuit's (ICs) is doubled in every two years. So the scale gets smaller (Table 1) and the performance of microprocessor shows an exponential growth.

The importance of the law was evident. The semiconductor manufacturing industry had created a predictive roadmap entitled, The International Technology Roadmap for Semiconductors which spans from 1971 to 2020 (Figure 1). This roadmap was established by five geographic regions that represent almost every chip manufacturers of the world.

The contribution of Moore's law has reduced the robust structure of the devices to handy gadgets over recent decades. All the smallest smart devices like smart phones, tablets, smart watches,etc. are the gift of the development of semiconductor.

Table 1 MOSFET Scaling [2]

Sl. No.	Year	Scaling
1	1971	10 µm
2	1974	6 µm
3	1977	3 µm
4	1981	1.5 µm
5	1984	1 µm
6	1987	800 nm
7	1990	600 nm
8	1993	350 nm
9	1996	250 nm
10	1999	180 nm
11	2001	130 nm
12	2003	90 nm
13	2005	65 nm
14	2007	45 nm
15	2009	32 nm
16	2012	22 nm
17	2014	14 nm
18	2016	10 nm
19	2018	7 nm
20	2020	5 nm
1	2023 (Future)	3nm
2	2024 (Future)	2 nm

Semiconductor Road Map

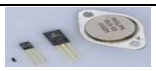
Name	Year	Image
Semiconductor	1874	
Vacuum Tube	1904	
Transistor	1947	
IC	1961	
1st Microprocessor	1971	

Figure 1 Semiconductor Roadmap

II. INDIA'S SEMICONDUCTOR INDUSTRY ISSUES

India is a powerhouse of semiconductor design. Almost every major semiconductor company has its presence in India, which design some of the world's most advanced chips. But once thosedesigns are completed, they are sent to USA, China, South Korea and Taiwan for fabrication which raises the big question regarding the development of semiconductor industry in India. There are some major issues.

A. Lack of Proper Infrastructure

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According to data, India currently imports all of its semiconductor chips as its manufacturing is a difficult job. SemiconductorFabrication plants, commonly known as FABs manufacture mainly various integrated chip circuits and silicon wafers which requires huge expenses to set up as manufacturing equipment depreciates fairly quickly. So no big industry or set-up is available in India at present where government have to play a proactive role by allocating the required budget. Actually, setting up a FAB can cost at least $(3-4) billion [3] and all the logistics and allocation of human resources may add up to even more. Also infrastructural requirements must include upgradation of the equipment constantly and their maintenance need an uninterrupted power supply and access to millions of litres of pure water where most of the river is polluted due to over growing population.

Fabrication plants also need long time to become profitable [4]. It may take at least (10-15) years' continuous operation of the plant to get a profit, otherwise end up losing thousands of crores of rupees.

B. Environmental Issues

The world giant industry Global Foundries makes chips through a complex process which needs clean environment along with expensive factory equipment. India, being a developing country most of its parts are polluted because of over-growing population. So, it is hard to find the clean environment required for making semiconductor.

C. Shortage of Resources and Electricity

Silicon is the main material that is used for making semiconductor. India don't have enough stored Silicon as compared to China, though India is the 3rd biggest country according to the no of Silicon production (370 Thousands of tons per year) [Table 2]. But the demand is greater than production [5].

Rank	Country	Silicon Production Rate (thousands of tons per year)
01	China	4,500
02	Russia	600
03	India	370
04	United States	320
05	Brazil	210

Table 2 Major Silicon Producers

Shortage of Electricity is another barrier. India don't have enough electricity to supply. But for the production of Semiconductor, electricity is main resource. At present India faces 1% of power shortage as of April-June period of this fiscal year, with an overall supply of 400.65 billion units against the requirement of 404.76 billion units [4]. But for establishment of semiconductor industry, the required uninterrupted power supply as per production rate, arrangement for huge power production units needs to be established.

D.No-Response Issue for Industry Establishment

The electronic usage saw a massive rise in 1970s throughout the world. America took the opportunity to set up its first semiconductor manufacturing industry resulting in the emergence of the Silicon Valley. While the US was mainly involved in the design phase, the manufacturing work was handed over to Taiwan owing to its cheap labour costs. India at that time was mainly reliant on the US and USSR (later Russia) for import in this sector and so lost the opportunity to capitalize the existing void in semiconductor industry. It was mainly because of the country's industrial policy of not investing the capitals in this sector at that time, made India's technological progress in this area way behind the developed nation .

So, India is seriously lacking in these departments. Also India's knowledge of Research and Developmental (R & D) activities for semiconductor manufacturing front end fabrication and back end assembly [5] is not so advanced. These factors played major role so far as foreign investors' financial assistance for establishment of semiconductor set up units were concerned in India.

III. SOLUTIONS FOR INDIA

However, the global chip shortage caused due to the COVID-19 pandemic have changed the situation as globally sizable parts of daily economic and essential activities are arranged online which is highlighting the importance of the chip-based computers, smartphones, and other electronic gadgets for daily use. The global education system is largely dependent on online communication mode. That's why the demand of electronic devices is increased a lot all over the world along with India. Earlier as the demand was too low to go for big semiconductor set-up, it was not initiated in developing country like India. But now it becomes a great opportunity for India to take advantage of this global chip-shortage situation to establish its own set up. Recent China-Taiwan geopolitical crisis gives the world an opportunity to rethink about the overdependence on China-Taiwan for semiconductor chips. India have to capitalize this golden chance to be a chip maker from chip taker [6,7]. For that purpose, few areas are pointed out here.

A. Long Term R&D Activities and Investment

Here case of Israel can be considered which become the bedrock of innovation as every semiconductor company has their R&D center in Israel. The reason is their investment on R & D. In 2022 they spend 4.8 % of their GDP in research while India's expenditure on research was only 0.7% of GDP [6]. India can't achieve success without focusing on scientific research and development on semiconductor sector progress

which may help India to gain a successful talent pool for semiconductor production. C2S (chips to start-up) program taken by Government will train 85000 young engineers to work for chip manufacturing. India currently have limited facilities like SCL(Mohali), GAETEC (Hyderabad), SITAR(Bengaluru).

B. Infrastructural Development

State-of-Art infrastructure is a necessity for semiconductor manufacturing. It needs continuous electricity supply for running 24X7. Entry level semiconductor factory needs 20+ million liter ultra-pure water per day. Also pollution-free environment as a single particle of dust can force a chip to compromise.

C. Investment and Government Incentives

Initiative taken by central or state governments and private investments.	Ongoing & Future semiconductor chip related projects
Karnataka government initiative	ISMC signed a MOU with state government this year with an investment more than 22000 crore for chip manufacturing facility.
Gujrat government Initiative	Under the umbrella of national semiconductor mission Gujrat state government introduce plan for establishment of DHOLERA SEMICON CITY in DHOLERA SIR .
Maharashtra government initiative	Foxconn(Taiwan) and Vedanta(India) are planning for a $22 billion investment for chip manufacturing facility in Talegaon of Pune.
Central government initiative	NSDC(National Skill Development Corporation) set to collaborate with Infineon Technologies for strengthening local semiconductor ecosystem.
Private Company collaboration.	American chip company Freescale already has R&D in India. Aricent (USA) acquire Indian chip design company Smart-Play with $163.06 million.
Central government initiative	IESA and Singapore semiconductor industry association signed MOU for the development of both countries chip industry.
Private investment	INVECAS set to invest $15-20 million for chip design centers.

Despite achieving success in designing, India's experience as a leading semiconductor manufacturer is not good at all. In 2007 due to the lack of industry policy, Intel, moved to China and Vietnam though initially had shown interest for India. Approaches by HSMC and Jaypee group failed to find success. But the announcement of $10 billion subsidy under PLI (production linked incentives) has the ability to be a game changer. Government have to assist in developing secured manufacture, friendly environment so that leading semiconductor companies can extend their hands in semiconductor industry initiative. Also state governments should take necessary steps like Karnataka and Gujrat Government to win the trust of foreign investors (Table 3).
Table 3 Ongoing and Future Projects (Government Initiatives) [8]

According to the reports by IESA (India Electronics and Semiconductor Association)India's semiconductor component market will reach $300 billion during (2021-2026) period. But with locally sourced semiconductor components which are still less than 5% in 2021, it will take years when projected cost hike will be $5-6 billion for a fabrication unit. So Indian government have to ensure its big Tech companies about the chance of profit from those investments.

D. India's Focus Area

To take care ofthe problems related to proper infrastructure, huge investment, lack of proper talent pool, low R & D budget and lack of local-made semiconductor chip related start-up [8], India should focus to strengthen its chip designing service capability as India already have an ecosystem for that with 24000 design engineers. In India, DRDO and ISRO develops semiconductor chips but only at strategic levels (Space and Defence). India lacks the capability to develop these chips at a commercial level. Thus, investment by local companies and collaborating with foreign partners should be emphasized on.
It can also focus on collaborating with OSAT (Outsourced Semiconductor Assembly and Test), ATMP (Assembly, Test, Marking and Packaging) where being major chip designer and vendor , they capture almost 50% of global chip supply chain and India can be a part of this supply chain. Here Central government scheme can inspire setting up of semiconductor fabrication units/ OSAT facilities/ sensor FABs / ATMP/ and silicon

E. China-Taiwan Crisis and India's Opportunity

Recent China Taiwan geopolitical crisis and the possible invasion in Taiwan and China-QUAD cold war forced chip-makers to rethink about semiconductor supply chain. To reduce over dependency on imported semiconductor, USA government recently passed most awaited CHIPS ACT with $52 billion funding to combat China technologically [8,9].

USA and EU may rely on India as a replacement of China. As the global chip shortage becoming acute in post pandemic world, TSMC (World's largest semiconductor foundry) can

make its manufacturing plants in India to end the global chip shortage as India have world's 2nd largest workforce. It is hoped that with help of PLIscheme, '**MAKE IN INDIA**' initiative, and with foreign direct investments, growth in research and Development India will be a chip taker to chip maker.

IV. CONCLUSION

From smart phones to data centers, personal computers to mighty supercomputers, from today's popular electric vehicles to future auto-driven cars, at the heart of these revolution is a piece of technology – Semiconductor. Semiconductor chip brings life in our daily used machines. Our very familiar silicon is that magic material that makes semiconductor chip revolutionary. This days to make semiconductor chip, more capable scientists are betting on new material like Gallium oxide. In this review paper India's current position and possibilities to be a chip maker is highlighted. India is looking for long term R&D policy, foreign investment and self-financing possibilities. The government policies and efforts to ensure India's future journey to be a potential chip manufacturing hub is also highlighted. Finally it is expected that addressing the major issues as discussed here, India will develop its own semiconductor industry in near future when its ambitious projects make India a leading semiconductor manufacturer in the world.

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VI. BIOGRAPHIES

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After Ph.D., Dr. Bhattacharyya worked as research assistant at Oak Ridge National Laboratory in their National Project on Nuclear Internal Conversion study and was awarded fellowship from University of Tennessee, USA (2001). Later she shifted to work in the area of Computational Electromagnetics and was awarded research grants from UGC, AICTE, and DST. She supervised Ph.D. work as empaneled supervisor of MAKAUT successfully. She has authored more than 50 publications in peer-reviewed journals and conferences.