International Journal of Scientific Research and Engineering Development-– Volume 3 - Issue 5, Sep - Oct 2020

Available at www.ijsred.com

REVIEW ARTICLE OPEN ACCESS

The Contents of Nigerians Semi conductor Fabrication Challenges and Opportunities : A Review Article

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Abstract

Nigeria remains a major recipient and cautious of importing electronics devices from abroad. This motivated authors to reviewed the global challenges and opportunities between distinct stages of productions and identifying the ongoing chance for Nigerians to fabricate semiconductors. The method was literature based conceptual. The study found that the barriers for Nigerians to fabricate semiconductors are much lower and have a greater chance of success, if they concentrate more narrowly on specific task for certain applications. Authors suggested that Nigeria should aim to learn more and look for tangeable policy to go into semiconductor fabrications technology.

Key words: Semiconductor, Fabrication, Opportunities, Challenges, Nigeria

1.0 Introduction

Semiconductor fabrications is important to Nigeria. We cannot conduct our normal modern daily lives, today, without this technology [1]. They have transformed our lives and our economy for the better and are giving rise to the technologies that will shape our future [2]. Semiconductors drive innovation and are key components of computers, telecommunications equipment, consumer electronics, automobiles, aviation, medical equipment, industrial and commercial machinery, and critical infrastructure [3].Semiconductors are the main sources of modern electronics and is the basis of computer chips that power today's growing multitude of electronic devices. It was semiconductor fabrications like the transistor and the integrated circuit were refined, helping to transform computers from unreliable machines (the size of a room into dependable devices) that fit neatly into pockets. Major application markets for semiconductors are: data processing (including personal computers, laptops, servers and tablets); communications (including fixed-line telephone systems, broadband internet, mobile phones, smartphones and more); consumer electronics (television sets, music players, gaming consoles and household appliances); automotive, comprising both light vehicles and trucks; and industrial (including infrastructure, rail services, the military, fossil and regenerative energy, smart grids, etc.) [4]. Semiconductors allow computers to run software applications, such as email, Internet browsers, and word processing and spreadsheet programs and to store documents, photographs, videos, music, and other data [5].

Nigerians are pretty great at importing semiconductor devices. They continued to lag behind among the committee of nations despite her abundant natural and human resources due to the inability of her government and people to identify and summon the will to invest massively in key areas that will make the most impact on her economy [1]. Despite being among larger consumers, they are economically dependant and almost no meaningful considerations were given to fabricate semiconductor. While semiconductor fabrications represent significants opportunities for every great nation in the global economy. These opportunities are needful for Nigerian to seek for it position in semiconductor design, research, and manufacturing in the global race to bridge the gap between adopted technologies that will define their future.

Therefore, It is time for Nigeria to accept economic defeat and have a fundamental review on the semiconductor fabrications technologies. This motivated authors to identifying the challenges and opportunities that would one step ahead help in bridging the gap between distinct stages of semiconductor fabrications in Nigeria.

1.1 Semiconductor Fabrication

Semiconductor is the material that partially conduct electricity. The semiconductor industry manufactures a huge variety of devices that have different fabricating requirements. Devices are based on the properties of semiconductors are transistors, rectifiers, modulators, detectors, thermistors and photocells etc. Semiconductor fabrication is a construction of a rectangular die , that is highly intricate set of patterned layers of doped silicon, insulators and metals that forms the functional heart of a microchip.

The wafer fabrication process is characterized by significant raw material use, high energy consumption, and extreme water-intensity [6]. The fabricating type for a particular device depends on different attributes including size, power dissipation, field-operating conditions, and last but not least, cost. The traditional production or assembly lines are usually organized to build products starting from raw materials or components, progressively transforming or assembling them in order to deliver end products or finished goods [7]. Once the assembly, testing, and packaging processes are complete, the finished semiconductors are sold to customers for use as intermediate inputs in the production of electronics [8].

The semiconductor production process can be largely divided into two sequential processes that are commonly referred as front-end and back-end production, and furthermore both processes contain many complex and sophisticated step. Semiconductor production can be divided into four general stages: (1) research and development (R&D), (2) design, (3) wafer production, and (4) assembly, testing, and packaging [9]. The change of business models during the 1960s gave rise to three types of semiconductor companies: (1) fabs or integrated chip manufacture (ICM) firms that designed, manufactured, and sold semiconductor products; (2) semiconductor foundries that catered to the manufacturing demands of customers; and (3) fabless companies that designed in-house but employed outside fabs and foundries to manufacture products [6], [10]. Each of these depend on advancement in semiconductor fabrications technology. For instance, wafers are produced in plants called fabs . Fabs are large manufacturing facilities, with tenths to hundreds of machines moving hundreds to thousands of wafers [11]. The manufacturing process of semiconductor chips often involves hundreds of processing steps being executed layer by layer onto a bare wafer [12]. Semiconductor processing demands a substantial utility infrastructure, including ultrapure gases, dry air and nitrogen, ultrapure water, exhaust, high quality

electrical power and more [13]. The chip fabrication process, for example, consists of as many as 300 steps executed by such tools as ion implanters, photolithographic steppers, deposition systems, oxidation furnaces, etchers and more [14]. Most times, the whole process is composed of a few repeating unit processes: thin film, photolithography, chemical mechanical planarization, diffusion, ion implantation and etching [12]. That is to say, each identical integrated circuits, called die, are made on each wafer in a multi-step process. Each step adds a new layer to the wafer or modifies the existing one. These layers form the elements of the individual electronic circuits.

1.2 Challenges in Semiconductor Fabrications

The semiconductor fabrication process is among the most complicated, knowledge-intensive manufacturing processes known [15]. It is becoming more difficult and more time consuming as these devices (microprocessors) are designed to take on more complex tasks, such as accelerating artificial intelligence computing, enabling automated driving, and supporting deep neural networks. This complexity, combined with the strong competition, forces semiconductor manufacturers to introduce several layers of controls in order to guarantee high yield [16]. This challenges in the semiconductor industry are identifies by the type and quantity of each wafer to be manufactured, the race to produce faster and smaller devices, diversifying applications relating to IoT devices and their faster paced evolution, new packaging technology and system miniaturization. The challenges and opportunities can be traced at least in part to the lack of a decision analysis framework in which the interrelation between manufacturing strategies and operational activities can be structured and then be integrated for solving the present problem as a whole [17]. According to one recent study, semiconductor producers base site selection decisions on tax advantages, supply of engineering and technical talent, quality of water supply, reliability of utilities, environmental permitting process and other regulations, cost of living for employees, and legal protection of intellectual property [18].

The costs required to fabricate chips have increased in a predictable manner, operating under what is referred to Moore s Second Law or Rock s Law, which says the cost of semiconductor tools doubles every four years [19]. For instance, setting up a new advanced technology fabrication facility can cost between US$5billion US$10 billion and take 1 1/2 years to complete [20]. Among the most expensive tools used in the semiconductor fabrication process are lithography tools [21].

1.3 Opportunities in Semiconductor Fabrications

Semiconductor fabrications started gaining global business recognitions since the industrial revolution in the late 19th century. Overall semiconductor industry growth is tightly coupled to global economic expansion and especially demand growth for consumer electronics; thus, growing wafer starts drives electronic materials consumption [22].

The following are five main driving opportunities in the semiconductor industry:

1) Competition: The semiconductor global value chain enables countries to focus on activities where they have a competitive advantage and trade for other goods and services [23]. America and China are having unwelcome repercussions (U.S.-China trade war) on one of the world s most complex and globalized industries (semiconductor fabrication technology), this is just to gain competitive advantage over the other. Of the over 288 industries compared for this analysis, the U.S. semiconductor industry ranks second out of all manufacturing industries in the United States [24]. There are five current trends that present both challenges and opportunities to U.S. SME firms: (1) The rise of China as both a producer and consumer of

semiconductors (2) opportunities created by greater use of artificial intelligence (3) the economic and physical limits of Moore s Law being reached (4) advances possible through the introduction of extreme ultraviolet lithography (EUV) tools and (5) foreign investment restrictions and export control reform [21].Many semiconductor companies are already utilizing digital tools to gain competitive advantage throughout the productivity. For example, the application of AI, IoT and analytical tool applications in the semiconductor industry extends from design, manufacturing, packaging and testing all the way to management.

2) Mergers and acquisitions: Technology acquisition, broadly described as a process in which firms buy technology from external sources, provides a host of benefits to companies, ranging from the development of new products, to gaining entrance into new markets [25]. Acquiring knowledge and technology involves adopting and adapting knowledge externally as well as creating knowledge internally through research and development. Semiconductor companies today are motivated to conduct domestic and cross-border M&A primarily for four reasons: to acquire advanced technology; strengthen market position and expand market share; search for cutting-edge applications; and expand their industry supply chains [26]. After slowing in the past couple years, semiconductor merger and acquisition activity strengthened in the first eight months of 2019 with the combined value of about 20 M&A agreement announcements reaching $28.0 billion for the purchase of chip companies, business units, product lines, intellectual property (IP), and wafer fabs between January and the end of August [27]. For example, Research by the Rhodium Group indicates that, before 2014, Chinese companies engaged in only six mergers or acquisitions (M&A) with U.S.-based semiconductor companies, valued at $213.8 million total [15]. The best strategy involves programmatic M&A, in which companies acquire at least one company a year, spending an average of 2 to 5 percent of their market capitalization, with no single deal accounting for more than 30 percent of their market capitalization [28].

3) Markets and Equipments: Top markets for semiconductors and semiconductor manufacturing equipment are China, the European Union, Japan, Korea (South), Singapore and Taiwan [3]. From 2014 to 2018, worldwide imports of SME increased from $51.4 billion to $92.8 billion and for that five year period total worldwide imports were approximately $298 billion [21]. International Data Corporation expects that semiconductors sales will grow at a Compound annual growth rate (CAGR) of 3.1 percent from 2014 to 2019 (though values will change from year to year) [29]. In 2016, 84 percent of worldwide sales of semiconductor manufacturing equipment are expected to be in five markets (Taiwan, Korea, China, Japan and the U.S./North America) creating a very concentrated market [10]. According to Semiconductor Equipment and Materials International (SEMI) in 2019, South Korea will remain the largest equipment market, followed by China and Taiwan [30]. Europe and the Middle East (primarily the EU and Israel) represent another 9 percent, and other markets (primarily Southeast Asia) account for the final 7 percent of the world market [31]. The Semiconductor Industry Association (SIA) estimates that 90 percent of the value of a chip is split evenly between design and manufacturing, with the final 10 percent of value added by assembly testing and packaging (ATP) firms [32], [15].

4) Policy and Investment: Policy has become the main strategy for many enterprises to meet in the aspect of challenges. For example, the policy of the retail industry should be penetrated all areas of the value chain involving consumer-oriented demand forecasting, personalized marketing, purchasing experience and intelligent customer service. The policy may be more

effectives when research funding; support for the development of increasingly powerful computers, market through defense and space-related acquisitions, data protection and security, cross-border data flows, competition, taxation and trade included. Semiconductor manufacturing is capital intensive, with a state-of-the-art wafer fabrication site costing billions of dollars and companies investing more than $10 billion yearly to keep manufacturing technology and facilities up to-date [13]. For example, the Chinese government has announced efforts to invest well over $100 billion over the next decade to catch up to the United States in semiconductor technology, artificial intelligence, and quantum computing [2]. Investing in semiconductor fabrications to increase productivity and develop new business channels, companies must overcome development policy challenges to provide new impetus opportunities

5) Research and Innovation: Semiconductor fabrications can not succeed without deep specialization and expertise. Research programs in areas such as materials science, computer science, applied mathematics, photonics, and chemistry are essential to future innovations in semiconductor technology [2]. The first step toward adopting this innovation culture is to adopt existing technologies and adapt them to the local situation. Also lack of collaboration between industries and education institutions creates a pivotal problem at the very first step [33]. A research and markets report also found a lack of qualified engineering and technology talent in the semiconductor industry [34]. Focused on Research and Development (R&D) is nearer term and narrowly applicable to semiconductor fabrication. Therefore, it is a time for Nigeria to shift for R&D into a close proximity semiconductor fabrications.

2.0 METHODOLOGY

The method of this study is literature based conceptual paper. In this study, a rigorous and systematic literature review on global players with respect to Nigerian challenges and opportunities in semiconductor fabrications technology was studied. The study also focused on the numerous advantages that should serve as a stimulant to policy makers for Nigerian to adopt and implement, which provide a perfect platform to figure out the missing links and managerial suggestions. The integrated information reviewed were expected prevaile the unseen future challenges and opportunities in the path forward to fabricate semiconductors in Nigeria.

3.0 Discussion of Findings

3.1 Challenges in Semiconductor Fabrications

The global semiconductor industry has never been without challenges and it will continue to grow during the next few years. Acquisition of necessary personnel, equipment and infrastructure, human capacity building, innovative products and services development through collaboration is mandatory for Nigerian, if they want to involve in Semiconductor fabrication technology. Semiconductor industries are driven by the often-quoted (and often misunderstood) Moore s Law, which postulates that the number of transistors on a single computer chip doubles every 2 years. There are more and more challenges for Nigeria to meet up with current situation (Moore's law) in global semiconductor fabrications.

Nigerians are pretty great at importing semiconductor devices, but truly great at nothing, since they can not fabricating it. Non of these electronic garbages are being fabricate in Nigeria, despite being among larger consumers. While Nigeria does not provide a favorable environment for this industry, others countries offer incentives to attract multi-billion dollar capital investments. Nigeria is trailing considerably far behind

these countries. And if semiconductor ores are obtained from rocks, then Nigerians have everything it takes to get the ores in abundance [35].

Promoting Nigeria economy will ultimately require a strong focus on advancing semiconductor companies. It is imperative for Nigeria to realize their challenges before entering semiconductor industry for them to come up with the best entry strategy. Newly established companies faces uncountable challenges when it comes to semiconductor fabrications and it is difficult for small companies to compete with big ones. The production of semiconductors occurs in three distinct stages: design, manufacturing, and assembly, test, and packaging (ATP) [36]. Today, not all countries in the world, intensively stand alone to execute all these stages. Countries with abundant labor perform labor-intensive tasks (e.g., assembly and testing), while countries with skilled labor primarily undertake technology-intensive tasks (e.g., manufacturing), and developed economies focus on knowledge-intensive tasks (e.g., design). Despite the fact that, the role of the government in the economy is largely to create the right environment for the private sector to succeed. Nigeria should not be silent or passive in the face of semiconductor industrialization by considering a multitude of factors such as policies, technologies, marketing, logistics and global strategies. In particular, policies should be put in place to encourage firms to develop technological and innovative solutions which are specific to the Nigerian economy, and also to stimulate the growth of indigenous firms with significant local content in their production inputs, ensuring the exploitation of the nation s resources [25]. Delivering on this strategy will require cooperation among government, industry, and academia to be maximally effective.

The Nigeria is falling behind its global challenges in some research benchmarks, producing many more bachelor s degrees, which was expected to generates the expertise in, physics, materials science, physical chemistry, electrical engineering, and other fields that are importance to the semiconductor industry. Nigerian's are looking for better work, where a large share of the population engaged in low productivity and low paying tasks. They do not have adequate technical expertise and resources to participate in such direction and management of technology development. And the transactions are highly concentrated in a small number of countries, of which Nigeria with 200 millons people by projection are expected to be one of them. Meanwhile, Nigeria is experiencing a shortage of such highly skilled workers, where large percentages of these relevant students were not expose to work in labs, advanced manufacturing and apprenticeships especially in semiconductor fabrication.

3.2 Nigerian's Opportunities in Semiconductor Fabrications

Today, semiconductor fabrication technology is highly globalized, and seamless transfer of patents and services integration process to the extent that companies focused on designing more specialized chips to process algorithms for hyper-specific applications, such as artificial intelligence to power self-driving cars, internet of things (IoTs), robotics to execute facial and speech recognition and other autonomous systems, which require a particular kind of computing power that can process massive amounts of data simultaneously and enhance digital encryption. The semiconductor industry is no longer dominated by a powerfulness of the largest players, but on making the best chips for specific purposes. According to industry experts, small semiconductor firms can compete effectively with larger ones by producing specialized chips for particular market niches or by developing new applications for their customers [37]. In such ways, Nigeria will have a much greater advantage, since barriers to entry in semiconductor fabrication are much

lower and they can concentrate more narrowly on specific chips for certain applications and niche markets.

Since no opportunities without it's challenges, and these challenges must be addressed to access these opportunities. No excuse for Nigerians not to fabricate semiconductor, since some Nigerians scientists are doing well in researches related to the field, despite being their major challenges are equipments to carryout some advance researches. And they are in needs of these equipments to compliment their research gap. Semiconductor fabrications could be the foundation to Nigerian broad economic growth and benefit would have the greatest impact in the long run. To gain this opportunities, Nigerian need to involve in the global semiconductor industrial sector with adoption to the following ambitious agendas:

1) Semiconductor fabrications does not rely on chips alone to achieve its productivity. Unlike CPUs, which need the most advanced processing technology available according to Moore's law. Nigeria need to go for the cheaper technology. For example, photovoltaic cell is also an important component in the advancement of Semiconductor industry. Nigeria with inadequate electric power, could concentrate itself on photovoltaic cells as the enabling technology of solar power, a key source of renewable energy that can serve Nigerian's interests in reducing dependence on petroleum and cutting greenhouse gas emissions. A strong Nigerian based investor can access such fabrications. Nowadays, semiconductor industry is becoming a key tool for energy harvesting with increasing its efficiency as well [38]. Concentrating on photovoltaic cells investment and innovation only by Nigerians government can increase the number of highly qualified scientists and engineers trained in semiconductor related fields and boosting their economy. Thus, opportunities also exist for semiconductor vendors to create energy efficiency to meet the demand of Nigeria electric power systems. Further more, if were opportune Nigerians are needed to go for multiple productivity to achieve maximum parallelism, resulting in a very large size of productions.

2) Global semiconductor technology have taken steps to consolidate their competitive positions, including acquiring potential competitors and expanding into complementary products or services. Nigerian innovative system is not as well-developed as those of other comparators. Their abilities to collaborate with other players, would determine their opportunities in fabricating Semiconductors. For example, Intel and Facebook are collaborating on the development of a new artificial intelligence (AI) chip. The greater opportunities lie with full-fledged participation in the global value chain of one of the world s most dynamic and vital industries [23]. Nigerians are need participate actively in an organizations or stakeholders composed of the world s leading semiconductor fabrications countries like China, Chinese Taipei, Europe, Japan, Korea and the United State and organizations/stakeholders like World Semiconductor Council (WSC), Semiconductor Industry Association (SIA), World Semiconductor Trade Statistics (WSTS), Semiconductor Research Corporation (SRC), Electronic Components Industry Association (ECIA), China International Semiconductor Executive Summit (CISES), Global Semiconductor Alliance (GSA), Semiconductor Equipment and Materials International (SEMI) etc. Collaborating with these Stakeholders would help Nigeria to go deep insights into building a resilient and growing semiconductors industry for Nigeria.

3) Given the nascent state of the semiconductor fabrications, Nigeria have no true emerged policy on the semiconductor fabrication. Nigeria is requires to frame a new and comprehensive policy on decisions and actions, of which semiconductor fabrication would be an important element. Formulating policies that take semiconductor fabrication into account of production is hard, but necessary. Finding adequate solutions requires

greater international collaboration and policy dialogue, with the full involvement of Nigerian government, personal or non-personal, private or public, for commercial or government purposes; volunteered, observed or inferred, sensitive or non-sensitive, so as to create a sustainable, and lucrative system to fetch good amount of investment. Implementing these policies will help Nigerian one step toward a future of innovation and economic growth, while also protecting it national security.

4) Nigeria remains a major recipient of used electronics from abroad. Nearly 290,000 tons of electronic waste was generated in Nigeria during the year 2017, which is likely to increase further due to high population growth rates, accelerated urbanization, high demand for electronic products, as well as disposal at their end-of-life [39]. Hence, the appropriation, utilization, disposal, and recycling of e-waste affect many stakeholders in society, including households who play an important role in the generation and management of this waste stream [39]-[41] Consumer electronics contain materials that are highly recyclable like aluminum, copper, silver or plastics. Recycling them properly helps conserve rare earth minerals and natural resource by giving them a second life instead of being landfilled. Thereby, creating a new opportunity for Nigeria to adopt in field of Semiconductor fabrications.

5) Nigeria need to invest more heavily on its people. According to the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce, 95,930 U.S. workers were employed in the U.S. semiconductor industry in 2014 [41]. More than half (56 percent) of these employees were production workers, who earned a total of $4.1 billion in annual payroll [8]. With such huge investment Nigeria would gradually reduce the number of unemployment and creating space for expertise if were put in place.

6) Nigerian agencies like National Environmental Standards and Regulations Enforcement Agency (NESREA), National Agency For Science and Engineering Infrastructure (NASENI), Sheda Science and Technology Complex (SHESTCO), National Office for Technology Acquisition and Promotion (NOTAP), Raw Materials Research and Development Council (RMRDC), and National Centre for Technology Management (NACETEM), Nigerian Communications (NCC), Commission Central Bank of Nigeria (CBN), Corporate Affairs Commission Energy Commission of Nigeria (ECN), National Power Training Institute of Nigeria (NAPTIN) e.t.c. are responsible for the oversight and administration of specific functions, such as an administration, preparing policy and issuing implementing regulations in accordance with the laws, funding and conduct of research and development. Their involvement in the semiconductor fabrications would be a great achievement in Nigeria economy.

Therefore, with these highlighted opportunities Nigeria should enable to address and position themselves to capture the business, scientific and technological challenges in the huge growth of semiconductor industry toward anticipated future.

4.0 Recommendations.

- The Nigeria needs to spike for specific semiconductor technology (focusing on a single industry and likely to be much more effective. For example, production of photovoltiac cells or LED bulbs), before embarking across the entire sector.
- Nigeria should establish a close collaborations in research and development to plan, fund, and coordinate pre-competitive platforms to attract talented semiconductor scientists and engineers from abroad to live and work in the Nigeria
- Nigerian government should encourages and supports of some relevant institutions by assigning personnel to assist the research efforts, including participation in

advisory and governing bodies, that acts as liaisons between the company and the researchers, benchmarking successfully measure or progress and more likely to stimulate intramural semiconductor fabrications.

- Nigeria should create agency with a clear mission and high-level of technical goals that support all members, and use those goals as the basis of opportunities and business partner to develop and manufacture simple products. The agency should be responsible for; exploring more comprehensive ways to support industries that are trailing for the fabrications, implementing programs with appropriate cost sharing between government and the semiconductor industries, providing funding and technical feedbacks, guidance in the selection and management process, coordinating/sharing research results and technology transfer, preparing seminars, workshops and other networking opportunities.
- Nigerian federal, state and local government should invests solely directly and indirectly to those that may have difficulty in those making the necessary commitment in semiconductor fabrications industries.
- It is also recommended that Nigeria should provide an open market-based environment with strong intellectual-property protection, access to affordable capital and leading-edge for academic research.

5.0 Conclusions

Semiconductor fabrications is widely open field for competitive advantage. It was concluded in this prospective study that Nigeria remain in clear disadvantage side, despite being among the larger consumers in the world of semiconductor fabrications. With the advancement in semiconductor fabrication technology and chip design, country like Nigeria could not have moved from futuristic speculation to cope with present-day reality. Therefore, it s time for Nigeria to step up and act in semiconductor fabrication to benefits it's citizens, and the entire world.

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