WELCOMING THE SEMICONDUCTOR INDUSTRY IN GHANA: CHALLENGES AND RECOMMENDATIONS – A CASE STUDY

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Abstract: The Semiconductor Industry is one industry that has been driving technological innovations for decades since its birth in the USA. Semiconductors form the building blocks of a wide array of consumer, medical and industrial electronics. The growth of many economies in the world can be attributed to the growth in the semiconductor industry in such countries. The global semiconductor industry consists of companies in the USA, South Korea, Taiwan, China, and the European Union. However, the semiconductor industry has no presence in the African region, in Ghana to be specific. This work investigates some challenges associated with the establishment of the semiconductor industry in Ghana, including challenges from basic research and development to manufacturing and marketing. The paper also highlights some recommendations which are key in laying the foundation for the entry of the industry in Ghana, including the provision of tax incentives, training of personnel, etc.

Keywords: semiconductor industry, semiconductor, electronics, Ghana

1. INTRODUCTION

The semiconductor industry consists of companies involved in the design and fabrication of semiconductors as illustrated in Figure 1 [1]. Semiconductor companies can be mainly classified into, fabless and pure-play semiconductor companies or foundries. The fabless ones are those which design chips to be manufactured or fabricated by the pure-play foundries. Examples include Qualcomm, Nvidia, Apple, etc. The pure-play companies only manufacture chips designed by fabless companies. Examples include GlobalFoundries, TSMC, and UMC. Some semiconductor companies, however, both design and manufacture their chips. Such companies are called integrated device manufacturers (IDMs). Examples include Intel, Samsung, and Texas Instruments [2].

Semiconductors can be categorized into seven types: logic, microcomponents, memory, analog, optoelectronic, sensor, and discrete components. Semiconductors are all around us. They control the computers we use to conduct business, the phones and mobile devices we use to communicate, the cars and planes that transport us from place to place, the machines used in the diagnoses and treatment of illnesses, the military systems that are used for war and defense, and the electronic gadgets we use for entertainment, just to name a few. Besides, the semiconductor technology makes these devices more compact, less expensive, and more powerful [3].

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It can be noted that the global semiconductor industry is dominated by companies in the United States, Taiwan, South Korea, China, and the European Union. For example, Figure 2 [1] shows the global semiconductor market shares for 2018. It can be observed from the figure that the U.S semiconductor industry is the leading provider of semiconductors to the world with a majority of global market share. However, there is no representation from Africa because there is little or no presence of the semiconductor industry in Africa, in Ghana to be specific. It is critical for developing African nations to develop policies, strategies, and action plans to design and manufacture semiconductors for economic growth and, also to prevent the situation that Africans are only consumers of modern electronics.

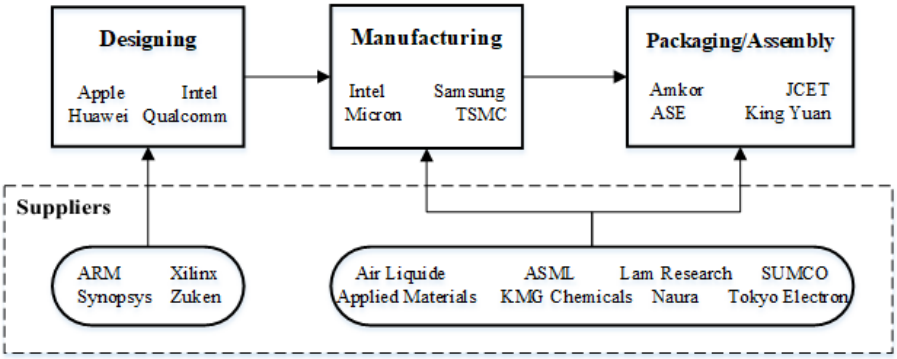

Fig. 1. Simplified illustration of the semiconductor industry, 2018.

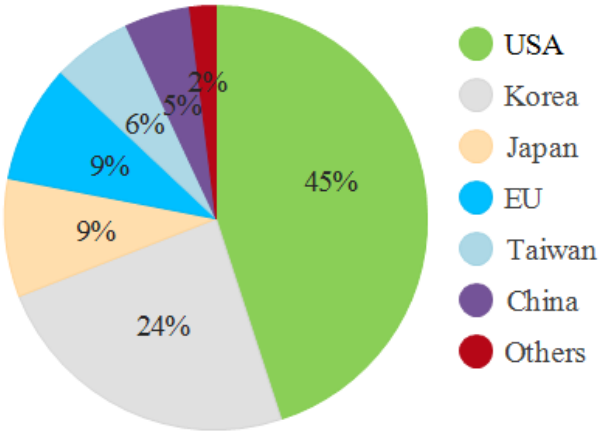

Fig. 2. Global market share of semiconductor production, 2018.

However, the establishment of the semiconductor industry in a region comes with some bottlenecks. Various works highlight these bottlenecks. Chih-Hung Hsieh et. al. [4] posits that, even though for developing countries, the acquisition of new technology from foreign countries is pivotal in the country's economic development, the cost and time taken - as a result of bureaucracies - for the importation of such technology could be a disincentive for the foreign company. [5] reveals that government policies coupled with a lack of skilled-personnel always have tolls on the semiconductor industry's growth in a country. [6] details the rising cost of Research and Development (R&D) as a major issue to grapple with in the semiconductor industry.

This work seeks to investigate the challenges associated with the establishment of the semiconductor industry in Africa, using Ghana as the case study. The work also highlights some key recommendations that would serve as a framework to welcome the semiconductor industry in Ghana.

2. METHOD

This study made use of both primary and secondary data sources. For the primary data, an online survey was conducted to ascertain the basic knowledge about semiconductor devices and applications among some engineering students of the universities and technical institutions in the country by administering some

questionnaires. The respondents were second (2nd) and third (3rd) year students in the following programs: computer engineering, electrical engineering, telecom engineering, materials engineering, industrial engineering, and mechanical engineering. There was a total of 303 respondents.

The questions asked bordered on the following: knowledge about semiconductor devices; usage of consumer electronics (mobile phone); and knowledge about some semiconductor manufacturing companies in Ghana.

The secondary data sources used include the Science, Technology, and Innovation (STI) policy document of the Ministry of Environment, Science and Technology, Ghana journal articles, and private organization reports and publications, etc.

The challenges highlighted in this work were identified by checking the findings against the state-of-the-art requirements for the establishment of the semiconductor industry. Further to that, some recommendations are made that could serve as a foundation for the establishment of the industry in Ghana.

3. CHALLENGES IDENTIFIED

3.1. Government policies on technology

Governments' policies have played an important role in the development of the semiconductor industry in every country in which such an industry has emerged. Even after the industry gains root in a country, it is never free of the visible hand of government intervention [7].

The semiconductor industries in Taiwan and Malaysia have grown massively as a result of the policy choices made by their governments. For example, the model of Hsinchu Science-based Industrial Park (SBIP), which led to the rise of Taiwan from a low-level assembler of goods to one of the most advanced high-tech manufacturing economies, has been one of the government's great technology policy triumphs [4].

However, Ghana, like most African countries, has no clear-cut policy on electronics and semiconductor technology in the Science, Technology, and Innovation (STI) policy document of the Ministry of Science, Environment, and Technology [8].

3.2. Human resource and research and development (R&D)

The semiconductor industry is a highly-specialized one that requires highly-skilled personnel. The industry typically requires electronic engineers, electrical engineers, computer hardware engineers, industrial engineers, computer software engineers, materials engineering, and mechanical engineering.

Besides, in the semiconductor industry, technology drives the path to achieve a competitive advantage. And the way to stay competitive in tomorrow's market is to invest in R&D today. R&D also requires highly-skilled personnel. R&D centers (RDCs) in domestic location is paramount to the success of high technology industry in developing countries [4].

Ghana currently has the challenge of a lack of scientists and engineers. In comparison to 4000 and 6000 scientists per million populations in developed countries, Ghana has only about 150 [5]. Besides, there is no R&D center for semiconductor or electronic technologies.

3.3. Training on semiconductor technology

In Ghana, there is a limited number of technical institutions or universities that focus on science and technology. Some of these technical institutions also lack the academic programs to train students on the emerging semiconductor technologies.

A survey was conducted to find out the knowledge about semiconductor devices among students in various disciplines of engineering in some selected universities and technical institutions in the country. Among the disciplines were: computer engineering, telecom engineering, industrial engineering, materials engineering, electrical engineering, and mechanical engineering.

On the knowledge about semiconductor devices, 52 % had fair ideas about semiconductors, 35% indicated they were taught in class but couldn't recall, the remaining 13 % had no idea at all about semiconductor devices. On whether respondents had modules on semiconductor devices and technology as part of their academic curriculum, 68 % responded positively, the remaining 32% indicated they had no class like that.

On the usage of consumer electronics, they all indicated they use smart-phones. When asked whether they knew about the components of the smart-phone, 41 % gave positive responses and 59% indicated they had no idea. On the knowledge about electronics manufacturing company in Ghana, 81% indicated there was no such company in Ghana, 19 % indicated there were such companies in Ghana. When the 19% were asked to mention the manufacturing companies, they rather mentioned some hubs and centers for the fabrication of printed circuit boards (PCB).

From the survey results, it can be inferred that only computer engineering, electrical engineering, and telecom engineering students had a fair idea of the semiconductor devices and technology. Meanwhile, the semiconductor industry is one that spans across most fields of engineering, including, materials, industrial, mechanical, etc. The demand for qualified personnel would mean the local universities and institutions would have to upgrade the number and level of their science and technology programs to include the basics of semiconductor devices and their applications.

3.4. Semiconductor market

The availability of a viable market for semiconductors influences the necessity for the establishment of such an industry in an area.

According to [5], setting up of a semiconductor industry could be affected by the domestic market. If the domestic market for the semiconductor device is small, multinational companies (MNC) could be discouraged from investing in such an economy. The market for semiconductors can be grouped into the following, depending on the application type: automotive, communication, industrial, data processing, and consumer electronics.

Within the last two decades, wide increases in the usage of personal computers (PCs) boosted demand for central processing units (CPUs) and memory chips, while the broad penetration of the Internet drove volume for ethernet equipment, network processors, and ASICs. The era of the smartphone started with the inauguration of the iPhone in 2007. This drove demand for mobile processors, while the birth of cloud computing pushed growth for server CPUs and storage. Now, artificial intelligence will likely be the catalyst that will drive another decade-long growth for the semiconductor industry [9].

The direct customers of semiconductors are mostly companies that build consumer electronic gadgets. Table 1 shows the top export markets for semiconductors in 2016. China tops because it serves as a hub for several electronic assembly and manufacturing plants. However, the table has no representation from Africa because there are not many electronics assembly or manufacturing companies in the African region.

Table 1. Top semiconductor exports markets for 2016.

Rank	Country
1.	China
2.	European Union
3.	Japan
4.	Korea
5.	Singapore
6	Taiwan
7.	Malaysia
8.	Mexico
9.	Thailand
10.	Vietnam

The government of Ghana would have to lay the foundation for the semiconductor industry by investing hugely in the electronics assembly/manufacturing industry. For example, Rwanda, an East-African country, has already

initiated this- through a partnership with Chinese company A-Link - by establishing the first smart-phone assembly plant in Africa, among others [10].

3.5. Semiconductor Financing

Semiconductor financing is another potential challenge that could be encountered. Venture Capitalists (VCs) have historically funded innovation and growth outside of large corporate R&D functions. From 1985-2005, there was a total of $14 billion invested and 1,100 semiconductor companies seeded. That has changed recently, with less capital and less VC interest in new semiconductor ideas. From 2012 to 2015, Venture Capital funded only $ 2.5 billion of capital. One of the major reasons for this shift is the high amount of capital and time required to fund a start-up semiconductor company, even a fabless one. It is estimated that it takes a semiconductor start-up at least $150m of capital to develop a new chip, and it costs $4 to $6 billion to build a leading-edge wafer fabrication plant [11]. As a result, VCs have progressively shifted their focus to other markets that require less capital and generate faster returns.

Thus, to start the semiconductor industry and support its growth in Africa, and in Ghana to be specific, there is a need for the government of Ghana to develop new financing models.

3.6. Taxes, levies, and fees

Excessive taxes, levies, and fees could be a disincentive to the establishment of a semiconductor industry in a country. Semiconductor manufacturing in Ghana would rely on the import of some special raw materials and parts which are not produced in the country. The cumulative effect of the different levies and taxes on imported materials can be large. For a typical consignment, these charges include import duties (0, 5, 10 or 20 % of the value), import VAT (15 %) and NHIL (2.5 %), processing fee (1 %), and GCNet charge (0.4%). These levies and taxes can range from 20.9 % to 40.9% of the item's value. Some items also attract additional excise duty (25%) and environmental levy (20 %) [12].

3.7. Energy crisis

One important factor to consider for the sustainable operation of the semiconductor industry is the availability of a reliable power supply. Power outage at a fabrication plant could destroy a lot of chips. For instance, a half-hour power outage at Samsung's fab near Pyeongtaek, South Korea, on March 9, 2018, damaged tens of thousands of processed wafers. It damaged as much as 3.5 % of the global NAND supply for March, which affected the flash memory pricing in subsequent weeks [13].

Ghana in the last decade experienced a rather elongated power crisis, which was a result of growth in power demand. This led to electricity rationing and blackouts. For example, between 2012 and 2015, there was an energy rationing where the utility switched off power to different areas according to a proposed schedule called load shedding [12]. Load shedding compounded the problem of manufacturers who endured electricity shortages and unreliable supply. More manufacturers had to acquire backup generators. Some manufacturers had to reduce their operating hours and reduced their staff numbers as a result of load shedding. In recent times, however, the Government has allowed the establishment of Independent Power Producers (IPPs) by foreign companies, to raise power generation to match the increase in power demand.

Nevertheless, there is still the issue of unreliable power supply which to a large extent, impacts the manufacturing industry. The manufacturing industries thus have to acquire their private power plants. Such factors, in turn, would lead to high production costs which would adversely impact the competitiveness of the locally manufactured semiconductors against imported ones.

4. RECOMMENDATIONS

Based on some of the identified challenges in this work, it can be inferred that it would be difficult for the Government to set up a national semiconductor design center and fabrication plant in the short-term, or for a private semiconductor start-up company to be established in Ghana or Africa as a whole. Instead, it is recommended that the Government puts in place initiatives and policies that would attract some key players in the semiconductor industry, such as Intel, Samsung, Texas Instruments, and others, to establish design centers in the country. Besides, some recommendations central to laying the foundation for the country to welcome the semiconductor industry are listed below.

4.1. Inauguration of a national program for electronics (NPE)

The Government of Ghana can commence a National Program for Electronics (NPE) to promote technological innovation of consumer electronics, medical electronics, communication electronics, and automotive electronics, etc. As part of the NPE, the government can allocate a long-term budget to facilitate talent cultivation, advanced research, and international collaboration. The NPE can coordinate with government agencies, universities, and corporations to develop an integrated framework of academia and industry in Ghana.

4.2. Establishment of electronics assembly/manufacturing companies

For semiconductor manufacturers to invest in Ghana, there should be an appreciable domestic market for semiconductors. Thus, it is recommended that Ghana invests more into electronics assembly or manufacturing companies that build consumer electronics from semiconductors.

4.3. Provision of a training fund

The government can make a special allocation from which semiconductor design and fabrication companies can draw their training funds for overseas training of Ghanaians before the commencement of operation.

4.4. Provision of a long-term investment tax allowance

The Government could give the semiconductor industry a long-term tax holiday and a reduced corporate tax thereafter. In addition to that, levies imposed by municipal and district assemblies where the plants would be located should be waived.

4.5. Provision of a special fund at a lower interest rate

The Government can provide a special fund channeled through the National Investment Bank (NIB) or GCB Bank. It can be drawn out as a long-term loan at a lower interest than the market rate to finance semiconductor manufacturing projects.

4.6. Establishment of a science park

The government can establish a national science park to be modeled on the famous Hsinchu Science Park (HSP) of Taiwan [14]. The park will feature high-tech companies, mainly involved in the semiconductor, computer, telecommunication, and optoelectronics industries. It will also house several R&D centers and technological hubs.

4.7. Addition of modules on semiconductors and emerging technologies to academic curriculum

It is recommended that modules on semiconductor and emerging technologies be added to most science and engineering programs in technical institutions and universities across the country.

4.8. Establishment of strategic alliances for semiconductor technology transfer

It is recommended that the government establishes strategic alliances with countries that have rooted-semiconductor industry for key semiconductor technology transfer. For example, the US-Japan strategic alliances in the semiconductor industry were instrumental in the growth of the industry in Japan by ensuring the transfer of technology between the two countries [15].

5. CONCLUSION

This study investigated the challenges associated with the establishment of the semiconductor industry in Africa, using Ghana as the case study. Findings indicated that there was no R&D center for electronics technology and innovation in the country; there was limited training on the basics of semiconductor devices and applications. Besides, it was found out that, the government has no policy on electronics and the semiconductor technology in the STI policy document of the Ministry of Science and Technology. Based on the challenges aforementioned and other challenges, there were some recommendations outlined. Among these recommendations are; establishment of a national program for electronics (NPE), the establishment of a national science park (NSP), tax-holiday policies, and other incentives to attract key companies in the semiconductor industry, like Intel, Texas Instruments, etc. It was also recommended that African countries focus on the establishment of electronics assembly or manufacturing plants which will serve as direct customers for the semiconductors produced by the semiconductor industry.

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