Technology in Society 36 (2014) 60–73

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Competitive strategies for Taiwan's semiconductor industry in a new world economy

Chi-Tai Wang*, Chui-Sheng Chiu

Institute of Industrial Management, National Central University, 300 Jhongda Road, Jhongli, Taoyuan County 32001, Taiwan

ARTICLE INFO

Article history:
Received 22 September 2013
Received in revised form 2 December 2013
Accepted 5 December 2013

Keywords:
Semiconductor
Taiwan
Industry life cycle
Competitive strategy
Sustainable development

ABSTRACT

Taiwan's semiconductor industry (TSI) has been a popular research subject. In particular, the small island country's characteristic fast follower approaches to starting a capital and knowledge-intensive high-tech industry – such as the semiconductor industry – and making it a success story provide valuable insight into the fast-changing dynamics of these industries and a role model for developing countries. For a long time, the primary competitive edges of TSI have been speed, cost, flexibility, and quality, enabled by policy formulation, bridging institutions, public infrastructure, vertical disintegration, entrepreneurship, and human capital. However, facing heightened competition, a change of status (i.e. TSI is no longer a follower but a forerunner in a relatively mature state), and a changing world economy, TSI needs to develop additional core competencies to remain competitive. This article discusses the approaches adopted by Taiwan's public and private sectors for such a purpose. By surveying a wide variety of data including laws and policies, national science and technology programs, industry news, market reports, and relevant literature, the study suggests that technology, value, sustainability, and brand are the additional competitive edges being developed for TSI. The paper also discusses potential obstacles for TSI in the foreseeable future.

1. Introduction

As the epitome of high-tech manufacturing, semiconductor manufacturing produces a staggering volume and variety of chips each year. These chips are the critical components for making electronic devices in application categories including computing/information (e.g. computers and tablets), consumer electronics (e.g. videogame consoles, TVs, and digital cameras), telecommunications (e.g. smartphones), automobiles (e.g. GPS), and aerospace/defense. With these devices, human societies have been advancing at an accelerating speed. The process of semiconductor manufacturing starts from growing silicon ingots (the raw material for making wafers) followed by a range of activities, including integrated circuit (IC) design, wafer fabrication, IC test, and IC packaging. The placement of finished chips on a printed circuit board marks the end of this process [[1], Fig. 1]. This manufacturing industry is characterized by long manufacturing lead times, increasingly short product life cycles, complicated manufacturing processes, and substantial capital investments. For instance, the wafer fabrication stage for making high-end videogame chips takes several months to complete. During the fabrication of chips and modules, the binning process (categorizing parts according to certain performance criteria) and the substitution process (using alternative parts to continue a manufacturing step) make capacity allocation a serious challenge for production and supply chain planners [2]. And to construct a brand new 300-mm (12-inch) wafer fabrication facility (a.k.a. fab), the required capital investments are measured by billions of US dollars. These characteristics make semiconductor manufacturing a capital and technology-intensive industry.

* Corresponding author. Tel.: +886 3 427 5033; fax: +886 3 425 8197.
E-mail addresses: ctwang@mgt.ncu.edu.tw (C.-T. Wang), s1572192@gmail.com (C.-S. Chiu).

0160-791X/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.techsoc.2013.12.002

All semiconductor firms must achieve an optimal allocation of manufacturing resources so as to survive in this fiercely competitive industry.

Called "Silicon Valley of the East" by Mathews [3], Taiwan is well known in the world for its highly successful high-tech industries, which have been the primary driving force of the national economy since the 1980s, and semiconductor manufacturing has unquestionably played the most significant role. How the small island country is able to develop such a successful semiconductor industry has been studied by numerous scholars, including Mathews [3], Liu [4], Chang et al. [5], Chang and Hsu [6], Tung [7], Chang and Tsai [8], Hung and Yang [9], Sher and Yang [10], Wu et al. [11], and Hu [12]. The significant status of Taiwan's semiconductor industry (TSI) is supported by the following statistics. According to the Industrial Technology Research Institute (ITRI) [13], Taiwan's largest public laboratory engaging in the R&D of advanced industrial technologies, TSI is ranked fourth in the world in terms of total revenues (US$48.8 billion in 2012 in a global market of US$297.6 billion). Currently, Taiwan owns the world's leading semiconductor contract manufacturing (a.k.a. foundry) service, leading outsourced IC test and assembly services, and second-ranked IC design services (Table 1). Currently, Taiwan houses the largest IC wafer fab capacity and the most complete semiconductor supply chain in the world (Fig. 1). As Hung [14] and Hung et al. [15] argued, the strong TSI has resulted in the country's unique position and competitiveness in thin film transistor-liquid crystal display (TFT-LCD) manufacturing because the two industries share similar IC fabrication processes [[15], Fig. 2]. In fact, by holding the second-place position in total revenues in 2012 (US$53.0 billion), Taiwan has continued to be one of the top TFT-LCD producing countries in the world. For the same reason of similar technologies being used, the strong TSI has also significantly contributed to the successful development of Taiwan's light emitting diode (LED) and solar photovoltaic (PV) industries [16], helping them to become the third and the second largest worldwide, respectively. Therefore, as Hou and Gee [17] and Mathews et al. [18] have argued, Taiwan's well-established IC infrastructure has provided a solid foundation to support the rapid development and advance of the other high-tech industries in the country.

The structure of an industry is a key determinant of its competitive advantages [21]. As indicated by various government officials and academics including Chang and Tsai [8] and Wu et al. [11], the primary competitive advantages of TSI have been speed, quality, flexibility, and cost, enabled by vertical disintegration and cluster effects. Vertical disintegration appropriately describes the structure of TSI. As illustrated in Fig. 1, TSI is a complex network consisting of firms specializing in some specific stage in the semiconductor manufacturing process, such as chip design or foundry. These specialist firms constitute a vertically disintegrated semiconductor supply chain that not only has become the most distinct feature of TSI, but is also unique in the world. By contrast, firms in virtually every other major country or region that produce semiconductor products, including the United States, Europe, Japan, and Korea, have mostly remained integrated in designing *and* manufacturing semiconductor devices. These firms are generally referred to as integrated device manufacturers (IDM). When entering the semiconductor market in the 1970s, Taiwan was weak in related sciences (e.g. physics, electronics, and materials science), technologies, and management methodologies; furthermore, Taiwanese firms were significantly smaller than those in competing countries and these small or medium-size firms lacked adequate resources, such as sufficient capital, skilled technicians, and established international connections, to start a high-tech business producing, for example, semiconductors. However, Taiwan had a diligent workforce whose average wages were significantly lower than what their foreign counterparts were making. In addition, flexible organizational and operational response to change, such as changes in market demands and design specifications, was an asset widely possessed by Taiwanese firms. With appropriate strategies and policies formulated by the Taiwanese government – in particular, the adoption of a *fast follower* approach [4,14,15,18]; the establishment of ITRI to lead the execution of that approach; and the provision of public funding and taxation benefits/allowances to encourage entrepreneurship – TSI was able to grow and find a niche position in the fiercely competitive market. The success of Taiwan Semiconductor Manufacturing Company (TSMC) in pioneering its "Dedicated IC Foundry" business model [22] stimulated the mushrooming of local specialist firms and accelerated the shaping of TSI to become a vertically disintegrated semiconductor chain. The strategic placement of these firms in a designated area created agglomeration and cluster effects, which increased the overall competitiveness of TSI significantly [7,9,10,23]. Some of the renowned specialist firms in TSI are shown in Table 2, including TSMC (the world's leading semiconductor foundry), United Microelectronics Corporation

Table 1
Taiwan's world-leading semiconductor industry [13,19].

Value chain	Category	2008	2009	2010	2011	2012
IC design	Revenue (US$ billion)	11.90	11.68	14.37	13.10	13.90
	Global share (%)	27.2	24.7	24.1	20.1	20.3
	World ranking	2	2	2	2	2
Custom IC fabrication	Revenue (US$ billion)	14.10	12.90	19.40	19.10	21.70
	Global share (%)	68.9	66.7	68.2	68.8	67.8
	World ranking	1	1	1	1	1
IC test & assembly	Revenue (US$ billion)	11.11	9.57	13.11	13.25	13.29
	Global share (%)	55.2	55.8	55.6	55.2	53.4
	World ranking	1	1	1	1	1