TRIPLE HELIX THEORY OF MANAGEMENT OF TECHNOLOGY EDUCATION (MOTE): AN EMPIRICAL STUDY OF A SEMICONDUCTOR DESIGN TRAINING

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ABSTRACT

This is a case study of management of technology education focused on semiconductor design by a major private university of Taiwan in optimizing strategies for success in the maturing semiconductor industry. Taiwan is one of the main production centers of semiconductor market, where demand of semiconductor and IC design service engineers are high. The semiconductor industry is essential in the computer industry, ICT field, and development of new electronic technology. Meantime, the management of technology education in Asia University designed to foster “T-shaped people” for the semiconductor industry. “T-shaped people” are professional engineers also known as an excellent leader, innovator and who can collaborate with other experts. The final implication is to facilitate successful collaboration between university and industry toward the development of semiconductor design program and serves as a guide for an economic development and IC design value chain.

Keywords: MOTE, TIM, semiconductor design training, triple helix theory, T-shaped people,

INTRODUCTION

Today, new technology rapidly changes that the professional manager must be able to change in a competitive environment and in globalized market. Technological industry requires managers who have specialized skills and who have a combination of deep theoretical and practical knowledge, as known as “T-shaped skills” (Madhavan & Grover, 1998). T-shaped skills, the proposition that creativity and new ideas spring from the interaction of different knowledge sets has found acceptance in knowledge literature (Simon, 1985), as well as in related fields such as social networks (Granovetter, 1973) and the emerging scientific literature on complexity (Kaufman, 1995). Universities prepare “T-shaped” managers through Technology and Innovation Management (TIM) degree programs to meet an industry requirement. TIM degree program includes Management of Technology and Innovation (MOTI), Management of Technology Education (MOTE), and Engineering Technology Management (ETM).
The competitive landscape of semiconductor industry changes due to technology convergence and greater global connectedness. Nowadays, a traditional business model is not suitable to support firm’s sustainable development. Future success requires innovative changes to existing business models to optimize capability in the semiconductor industry. Here, management of technology education prepares technology professionals toward to optimize their capability, improve industry centricity, and increase university-industry collaboration. Our assumption concentrates on promotion of T-shaped managers focuses on semiconductor industry.

The research structure basis on “triple helix theory” that includes research-working relationships among three constituencies: the universities, students, and customers (Kim, Kim, & Yang, 2012). Today’s rapid technological advances require university to be more innovative to meet industry demand. A university will not be successful alone, due to lack of resource; however the triple helix theory brings collaborative opportunities. Theory developed based on case study, literature review and an actual data (Perrow, 1986; Pfeffer, 1982; Eisenhardt & Graebner, 2007). However, scholars argue whether the empirical results have connection with development of a testable, relevant, and valid theory (Glaser & Strauss, 1967). Thus, it is important to link the theory and case study to reach testable and empirical validity (Eisenhardt, 1989b). Therefore, this case study base on triple helix theory concentrating three constituencies: Asia University, students and industry focusing on a new topic area of semiconductor design. Case study focuses on a virtual device fabrication training semiconductor design program under MOTE objectives. Case study identifies the gap between university, students and industry and addresses solution to the gap through accurate and testable method.

Technology and innovation become a key aspect of the economic growth furthermore influences to the competitive advantage of the industry that need to be managed effectively through specialized education. Therefore, in past 25 years, universities concentrates on technology and innovation management (TIM) in their graduate education programs and most management and engineering schools cover management of technology and innovation topics in the offered program (Yanez, Khalil, & Walsh, 2010). TIM pedagogy focuses on management of technology, R&D management, and innovation management to prevent from any failure faced by managers. Business administration and management students, moreover information technology students take management of technology education included to the TIM.

Development of theory is a central activity in organizational research (Eisenhardt, 1989b). Traditionally, researchers have developed theory by combining observations from previous literature, common sense, and experience (Eisenhardt & Graebner, 2007). However, the tie to actual data has often been tenuous (Perrow, 1986; Pfeffer, 1982). Yet, as Glaser and Strauss (1967) argue “The discovery of grounded theory: Strategies of qualitative research”, it is the intimate connection with empirical reality that permits the development of a testable, relevant, and valid theory. In this study, we focus on the related research strategy of theory building from empirical case study. Through this case study, we analyze, how Asia University takes an active role to conduct semiconductor design program through MOTE to achieve long-term and systematic knowledge. MOTE prepares T-shaped skills of students, develops links between university and industry, and transfers theory to practice enabling innovative training for semiconductor design. Case study defines key roles of each party under the ‘triple helix’ theory, and highlights the focus of the management of technology education. The final implication is to facilitate successful collaboration
between Asia University, students and industry toward the development of semiconductor design program and serves as a guide for an economic development and IC design value chain.

THEORETICAL BACKGROUND

Management of technology

Management of technology (MOT) was stated by “The hidden competitive advantage” report of National Research Council of USA in 1987. The MOT literacy is basic literacy (Miaoulis, 2010). Nowadays, the high–tech business, commercialization of innovative production and technology innovation are hot topics among universities, researchers and entrepreneurs. Management of technology education requires integrating the relevant parties under an appropriate theory to achieve successful result. The technology and business disciplines become essential for present workforce that an understanding of technology. Its current capability and its future potential are integral to business decision making (Donofrio et al., 2008). The technological capability must be combined with complementary management skills for commercial success (Bennett et al., 2001).

University must embrace a renewed human centered focus that attract a diversity of students, and must have a direct impact to increase competitiveness in global arena (Craig, 2010). Business leaders need innovation partners to conduct research and deeply steeped in the issues and dynamics of technology (Donofrio et al., 2008). Surveys conducted in 9 academic departments reported that collaboration benefits academy, students and industry, which speeds up fundamental and applied research, generates income for academics, and provides career opportunities and optimal incentives for students, and increases productivity of industry (Ankrah et al., 2013). Changing curriculum on a national scale is challenging issue, however, if it accomplished in one university, it would be easier, moreover, if teachers have a background in technology or business discipline, it provides ready to access to professional development courses (Miaoulis, 2010). The professional course is more easy training the high quality student to meet firm’s demand human resources, special on semiconductors high-tech industries. Professors from technology education program are qualified to teach technology components of the curriculum (Miaoulis, 2010). Technology and business educators must be prepared in their curriculum, must have research facility and science knowledge of textbooks (Miaoulis, 2010). Consequently, the professor of MOT will was examined professional technology knowledge that is essential condition.

Overall, the MOT education approves learning goal that learning by doing, learning by using and learning by interacting could increase efficiency of production (Bennett et al., 2001). The MOT training course through learn foundation theory by education and to do test by practice. That is a good education approach for training high-tech engineers of integrated circuit (IC) design industry.

The university and industry collaboration

Universities struggle to keep abreast of fast changing dynamic nature of work (Donofrio et al., 2008) and become entrepreneurial realizing commercial value of the scientific research and innovation (D’Este et al., 2012). Universities found that they need cross–disciplinary programs and degree in order to compete, moreover it difficult to provide aspiring knowledge (Donofrio et al., 2008). Instead, universities could develop broad relationship with funding stakeholders for value added production of technology development (McAdam et al., 2012). University and industry relations, so
called double helix are an important for concentration of technological trajectory (Ivanova & Leydesdorff, 2014). University and industry collaboration is a good predictor of effective technology transfer (D’Este et al., 2012). University and industry relations shape each other in a co-evolution and lead to relatively stable trajectories, however university–industry–government relations, so called triple helix model makes trajectories unstable (Ivanova & Leydesdorff, 2014). University and industry interaction creates a culture of innovation (Craig, 2010) and drive solutions to pressing problems (Donofrio et al., 2008).

The transfer of technology and R&D activities from research institutions to industry is neither easy nor smooth (McAdam et al., 2012). According to the Ankrah et al. (2013), the university and industry collaboration brings knowledge transfer from other industries and has economic and financial benefits, access to new technological development, business opportunities, intellectual property rights and enhance of reputation. Ankrah et al. (2013) mentioned university and industry collaboration creates challenges for universities, (1) instead of focusing teaching and research activities; it starts to concentrate to business; (2) conflicts between researchers and practitioners; and (3) risks to loss control of vital technology. However Ankrah et al. (2013) did not identify the above mentioned challenges. Moreover, D’Este et al. (2012) stated that no studies examined whether the skills of academic researchers influence to the discovery of technology and exploitation of entrepreneurship. D’Este et al. (2012) also found that academic researchers with collaboration experience could contribute to research source and able to undertake entrepreneurial activities.

McAdam et al. (2012) stated stakeholder relationship model indicates that stakeholder and industry both has high interdependence to one another. In rapidly changing world, technological companies must achieve competitive advantage by promoting technological skilled personnel in the firm through learning (Martin–Rojas et al., 2013) and partnership with universities. The most successful example is IBM, which helps universities to create integrated and interdisciplinary Research Center to bring leading students from multiple disciplines to address broad and real–world needs (IBM, 2009).

Double helix theory builds an efficient relationship, physical proximity and economies of scale. In accordance with the double helix theory, university–industry relationship provide knowledge based system and technology based output (Leydesdorff & Meyer, 2006). This collaborative framework enhances the role of university, students and industry in innovation, respectively and stresses technological revolution, importance of techno–economic renewal and market demand network (Benner & Sandstrom, 2000). A ‘double helix’ theory generates innovation strategies and provides scientific and technological revolution, relevant human resources, and financial and policy contribution (Leydesdorff & Meyer, 2006; Marques et al., 2006).

**T-shaped people**

The company must collaborate with university to develop their employees with deep skills and sufficient understanding so called a “T-shaped person” through consensus–innovation–knowledge (IBM, 2009; Ivanova & Leydesdorff, 2014). T–shaped professionals have problem solving (depth) and complex–communication (breadth) skills (Donofrio et al., 2009). IBM initiated to create T-shaped professionals to feed its demand of qualified people (IBM, 2009). D’Este et al. (2012) point out that university and industry collaboration is important for development of skills required for entrepreneurship and equips academic researchers with complementary skills. Moreover, the
collaboration is based on knowledge transfer between universities, industry and wider community
(McAdam et al., 2012). Spin-offs can be seen effective for “linear” transfer knowledge from science
to industry based on transfer of intellectual rights or transfer of personnel (Treibich et al., 2013).
Young professionals need to successfully lead an organization in the economy through T–shaped
development (Spohrer, 2014).

T-shaped people means the vertical stroke of the “T” is the depth knowledge and horizontal stroke is
breadth skill (Brown, 2010). In technological industry, the company must have top management with
high technology background, technological skills and technological competencies that way company
will have competitive advantage in the market (Martin–Rojas et al., 2013). These technological
variables direct to build T–shape people, moreover if top management and they employees
constantly renewed and improved technological skills along with scientific knowledge to obtain
deeper and broader knowledge and skills, it will maximize the benefit of the company (Martin–Rojas
et al., 2013). Knowledge development plays primary role in shaping a technological paradigm
(Ivanova & Leydesdorff, 2014).

Future trend specifies that industry focuses on service growth that increases mutually beneficial
interactions, decreases unproductive interactions and enables T–shaped people to lower
coordination costs (Spohrer, 2010). The company may create culture of innovation and foster the
innovation through enhancing their engineering workforce with the latest approaches (Craig, 2010).
T–shaped professionals are good at collaboration and innovation, as well good at solving new
problems in their area of depth (Donofrio et al., 2008). T–shaped people are learners at later stages
in their careers that the challenge is T–shaped people learn more longer and more complex way
(Donofrio et al., 2008).

Theoretical of Case study

Scholars have used case studies to develop theory about topics as multiple sectors as group process
(Edmondson, Bohmer & Pisano, 2001), internal organization (Galunic & Eisenhardt, 2001; Gilbert,
2005), and strategy management (Mintzberg & Waters, 1982). Eisenhardt and Graebner (2007)
stated that when research basis on theory and data from case study, than it provides a logical link
and meaningful interpretation of the data. Theory building from cases study known as classic
scholars (Whyte, 1941; Chandler, 1962) as well as the scholars of highly regarded AMJ articles
(Dutton & Dukerich, 1991; Sutton & Raphaeli, 1988 Sutton & Raphaeli, 1988) have used the method.
Case study research focuses on describing, understanding, predicting and controlling the
organization and/or culture (Woodside & Wilson, 2003). However, papers that build theory from
cases are often regarded as the most interesting research (Bartunek, Rynes, & Ireland, 2006) and are
among the most highly cited pieces in AMJ (e.g., Eisenhardt, 1989a; Gersick, 1988). D’Este et al.
(2012) exploit data from a survey of UK academic researchers, including engineering, computer
science, chemistry, physics and mathematics that asked for their interactions with industry. It is aim
on industries case study In addition to, reviewed journal articles to know the type of research
collaboration with institutions and individual and quality of research (D’Este et al., 2012).

Building theory from case studies is a research strategy that involves using one or more cases to
create theoretical constructs, propositions and/or midrange theory from case-based, empirical
evidence (Eisenhardt, 1989b). Case studies are rich, empirical descriptions of particular instances of
a phenomenon that are typically based on a variety of data sources (Yin, 2009). Central to building
theory from case studies is replication system and logic (Eisenhardt, 1989b). That is each case serves as a distinct experiment that stands on its own as an analytic unit. Like a series of related laboratory experiments, multiple cases are discrete experiments that serve as replications, contrasts, and extensions to the emerging theory (Yin, 2009). But while laboratory experiments isolate the phenomena from their context, case studies emphasize the content rich, real-world context in which the phenomena occur. Exploring empirical research begins with strong grounding in related literature review, identifies a research gap, and propose research questions that address the research problems. But when using theory building from cases as a research strategy, researchers also must take the added step of justifying why the research question is better addressed by theory-building rather than theory-testing research. The implicit assumption is that theory building from cases is less precise, objective, and rigorous than large-scale collection data and hypothesis testing.

The challenge of justifying inductive case research partially depends on the nature of the research question. For theory-driven research questions that extend existing theory (Lee, Mitchell, & Sablynski, 1999), a researcher has to frame the research within the context of this theory and then show how inductive theory building is necessary. However, the research question is tightly scoped within the context of an existing theory, and the justification rests heavily on the ability of qualitative data to offer insight into complex social processes than quantitative data. This study through double helix model has rested on case studies (Ivanova & Leydesdorff, 2014). We will explore Asia University MOTE training program how to cultivate T-shaped people for IC design and semiconductor industry demand.

**EMPIRICAL CASE STUDY**

![Diagram](image)

*Figure 1 Research conceptual architecture*

The research conceptual architecture is basis on case study of Asia University that how university deals with the management of technological education in semiconductor design. Asia University will be a primary source and the main methodology focuses on teaching, learning and document
collection, include interview, questionnaire, and observations (Yin, 2009; Eisenhardt, 1989b; Woodside & Wilson, 2003). The core variables of the case study will be professors, students, and practitioners in management of technology education concentrated in semiconductor design (Woodside & Wilson, 2003). Qualitative data will be collected in accordance with the case study that will be useful to understand the relationship based on triple helix theory. Video and teaching notes will be used for empirical evidence; furthermore, it could be adopted in different universities and policy research.

Figure 1 shows Asia University through training program MOTE curriculum cultivate the T-shaped people for semiconductor industry demand. The architecture states where interactive knowledge/technology transfer between both university and industry. In current, University make knowledge transfer or technology transfer of professor’s research result to industries sector. Otherwise, industry sector also can feedback their technology to MOTE department of university what is building the foundation theory of creative new technical products. Asia University professors through curriculum educate and train students to know “How do design the best semiconductor circuit”? In the meantime, University and curriculum happen two path doing knowledge spillover with each other. The objective of training course what cultivate T-shaped people offer to semiconductor industry’s IC design engineers.

University will be asked by the question “How semiconductor design training conducts through management of technology education?”, “What is the pedagogy method?”, students will be asked “What am I learning?” and “How we will benefit from the management of technology education?, and industry will be asked by the question: “How we will use semiconductor design?” (Eisenhardt, 1989a) and “How can we get the T-shaped people”? (Brown, 2010). These questions are to achieve the deep understanding of case study using multiple research methods, such as direct observation, questionnaire and document analysis within multiple time periods (Eisenhardt, 1989b; Eisenhardt & Graebner, 2007; Yin, 2009; Woodside, 2010).

It need tools assistant MOTE training program curriculum that achieves the goal of MOTE program, and through the check list it make sure the training program is ready or no. Table 1 show out the check list that contains highlighted tools of a professor, a student and industry that knowledge transferring from academy to industry through students, engagement process and collaboration of relevant parties. This check list is very easy to do checking when the training program at before begin the professors, students, and industry sector make it. The mentor of program double check the list that make sure every item ready to run training project.

Table 1. Check list of tools of curriculum

<table>
<thead>
<tr>
<th>Tools</th>
<th>Professor</th>
<th>Student</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative analysis</td>
<td>Strong conceptual theory</td>
<td>Clarify to know conceptual theory</td>
<td>Can applied the conceptual theory</td>
</tr>
<tr>
<td>Quantitative analysis</td>
<td>Strong quantitative analysis software</td>
<td>Clarify to know how using the software</td>
<td>Can applied the software/tools</td>
</tr>
<tr>
<td>Observation</td>
<td>Clarify observation method</td>
<td>Maintaining power observation skill</td>
<td>Can applied the observation skill</td>
</tr>
<tr>
<td>Academic approach</td>
<td>Strong Academic</td>
<td>Clarify to know</td>
<td>Can applied the</td>
</tr>
<tr>
<td>Tools</td>
<td>Professor</td>
<td>Student</td>
<td>Industry</td>
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<tr>
<td></td>
<td>knowledge/method</td>
<td>applied method</td>
<td>academic approach</td>
</tr>
<tr>
<td>Practical</td>
<td>Clarify to know practical approach</td>
<td>Strong powerful practical skill</td>
<td>Can applied the practical approach</td>
</tr>
<tr>
<td>approach</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interview</td>
<td>Strong interview procedure/skill</td>
<td>Clarify interview procedure/skill</td>
<td>Clarify to know interview procedure</td>
</tr>
</tbody>
</table>

The result of the research is to provide description and assurance of triple helix theory based on case study and causal analogies (Walton, 1992). Core variables of case study must gather information related to the semiconductor design through management of technology education that enables innovation, manufacturing, diffusion and adaptation (Woodside, 2010).

The collaboration leads to technology innovation through education program, accelerate learning growth and enhance the knowledge transformation. A ‘triple helix’ theory is an appropriate framework providing collaborative network involving relevant parties. The concept of a ‘triple helix’ theory is a highly integrated structure that quickly responds to changing educational conditions and market opportunities.

Courses of the MOTE program are: (1) A Method of Designing a Novel 800V Multiple RESURF LDMOS Utilizing Linear P-top Rings; (2) LDMOS Device Physics and Design Principle.

The curriculum focuses on the followings:

- Introduction
- Motivation and Objective
- Device Structure and Concept
- Linear P-top Mask Design
- Technology Comparison
- Mesh Strategy
- 3D Simulation
- Charge Balance Sensitivity

Asia University created a “virtual device fabrication (VDF)” in 2007. The purpose of the VDF is to create MOTE programs for semiconductor industry requirements. This MOTE training is designed for graduate and undergraduate (the fourth year of computer science) students in separate programs for each. The objective of MOTE training includes: (a) develop new physical models through collaborations among CMC members, (b) develop computational model, tools and other means of technology transfer that supports the broad user base for computational microelectronics, (c) develop curricula and teaching methods that support the infrastructure of computational electronics, and (d) provide educational materials and organize meetings to enhance information exchange and transfer of knowledge with microelectronics industry.

The main goal of the program is to contribute to the growth and development of computational microelectronics by providing the fruitful exchange of ideas and training for microelectronics
engineers, numerical analysts, and computer scientists, who are applying existing simulation tools in a novel way and who are developing new computer-aided engineering methods to tackle open problems in the area of microelectronics. An additional outcome from VDF include the 60+ papers publication on scholarly journals, 20 patents pass applied, and the graduate students continuing their studies in Ph. D programs. The VDF’s students also are very popular for semiconductor firms who they are 100% in employment. This empirical study of VDF is a successfully case of MOTE programs.

The T-shaped person training at the lab are described as follows:

1. We have several industrial partners whose offer the current problems and ask our to solve problems for them. So, We take the problems and start using our students with various groups to solve the problem interactively with the industrial partners such as TSMC, Vanguard, Nuvoton, Maxchip, Amazing Microelectronics etc. The problems are all related to intelligent power devices, analog, device design and simulations, and require to use our device and process simulators to find the solutions.

2. We have taught my students a very key course titled: “Product design and development” which is based on the textbook by Steve Eppinger and Ulrich of MIT. We got the authorization from the author for the ppts materials and we teach the courses with several case study such as "IDEO", "Apple Computer", "Samsung marketing", "Pixim".plus we used the "TRIZ" software for training them to use TRIZ to find possible solutions for the problems.

3. We use both “product design and development” and industrial projects (each student will do at least 5 various real projects to train them to be a T-personal. Not only the student learn the product realization process to the market needs, but also student will finalize the solution with a patent. So, we have present almost 70 international papers and 18 international patents application (out of them, 5 US patents have been awarded). This shows what we manage to make T-person training a success case.

4. The KPI of our program is to have 100% job offered and 100% accepted by schools like NCTU and NTHU in Taiwan whose continue studying Ph. D. program.

DISCUSSION

The MOTE triple helix provides substantial outcome benefits for each of the three major participants as well as the development of semiconductor design industry and can serve as a guide for industrial economic development for IC design supply chains. The MOTE program of Asia University not only training “how to do design semiconductor circuit” but also education the solution problems ability and management project skill. These students whose they through the MOTE program course and pass oral test of master thesis. They can got the master degree certification.

Training the student’s design skill is the curriculum core values but not only this one. It included education personal relationship, teamwork capacity, leadership skill of project. This MOTE program also ask every one present their intelligent of collaboration on teamwork. Consequently, the program ask every student rotation role play and changeable assume the leader of project. That approach is a mean fullness let student understand to each other role/task and need what helps. The result shows through the rotation role play that can enhance teamwork efficiency and performance. We also find the most students can consideration to each other when they joint the
project, and prepare prepositioning for next one pick up the task. The students changeable to more motivation, carefulness, and professionalization that can help solution the problems and reduce mistake.

These students of training program whose are come from different country. They have difference culture, language, and basic education background. Their thinking is different and often occur conflict when they to do communication for project process schedule. The leader of project should be mediate conflict to each other and conciliate team member emotion. Integration personal opinion of member conductive into goal of project what improving cognitive conflict. Solution the conflict need spend much time and more patient to hear every member different opinions.

**FINDINGS**

High-tech industry requires managers who have specialized skills special in semiconductor design industry, and who have a combination of deep theoretical and practical knowledge, as known as “T-shaped skills” peoples. The findings confirm the adaptability of the triple helix theory in solving the problems and controversies surrounding MOTE programs that involve university support. The semiconductor design program can transform student into “T-shape people” in training IC design engineers. T-shape people who not only a fundamental knowledge of science and engineering, but also include strong understanding of the complex social, political, economic, and environment implication. The results reply to scholar stated the T-shaped skills personal possess multiple functions on job position (Simon, 1985; Van Wyk, 2010).

Asia university IC design training program is a successful MOTE case. The training program cultivate many semiconductor design engineer who are very popular for IC industry. The graduated student is 100% obtain employment offer from IC firms. This is very successful MOTE case in semiconductor sector that also is a paragon for other MOTE program. This study states the MOTE program in IC design that also can to do indicate for the other high-tech training program. The implication can offer MOT education reference.
APPENDIX A THE OUTCOME LIST OF VDF IN ASIA UNIVERSITY

Energy Capability of LDMOS as a Function of Ambient Temperature

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Introduction

- LDMOS has become the most important member of power semiconductor devices because of the excellent power capability, reliability, high voltage, high frequency applications, and also because of its superior performance with respect to linearity and efficiency.
- However, design improving and transistor operation results in performance degradation or even thermal runaway.
- Hence understanding the thermal effects, which is one of the primary failure mechanisms, is very important for designing and operating the device to have high energy handling capability.

Analytic Model

- Given function approach is followed as in Li and Liew et al. (1) and energy to failure is obtained to be:

\[ E = \frac{P}{2} \left( \frac{T - T_{th}}{T_{th}} \right) \left( \frac{T_{th}}{V_{th}} \right) \]

where \( P \) is magnitude of the constant power, \( T \) is critical temperature, \( T_{th} \) is the thermal temperature, \( V_{th} \) is the specific heat capacity (J/K), \( V_{th} \) is the thermal conductivity (W/mK), and \( \alpha \) is the thermal diffusivity (m^2/s), given by \( \alpha = \frac{\delta^2}{2c} \).

More results

- Energy capability of the simulated device was calculated by integrating the product of \( P \) and \( \alpha \) along the plate width (1), pulse width (1), pulse width being the time taken by the device to fail.
- Simulated Energy capability was compared with the Energy capability calculated from the analytical model.

Background

- Localized near surface p-zone was considered and analytical model for thermal breakdown had been developed in the past [1].
- The major complexity in this method is the strong temperature dependence of the material parameters thermal conductivity (\( \kappa \)) and thermal diffusivity (\( \alpha \)). Using the idealized expression for the effective values of \( \kappa \) and \( \alpha \) is very important [2].
- Vickers et al. [1] and Vickers et al. [4] have proposed constant values for \( \kappa \) and \( \alpha \) for all the ambient temperature conditions and had concluded that energy capability has a linear dependency on ambient temperatures.

Results

- An (NPN) LDMOS device structure was used as DUT applying a drain to source voltage pulses (Vds) a constant drain current (Idd) was maintained for a time long enough to destroy the structure.

- The temperature drop increases the effective interface concentration inside the device and the device is assessed to fail when the critical temperature is reached, inducing high leakage current.

- Similar approach was followed for different ambient temperature ranging from 70K to 300K and the temperature rise in the device along with the transient time was obtained.

Analytical Modeling

- An analytical heat flow model is necessary for calculating both drift and thermal safe operating area.
- A cross section of dimension 1x1 m on a semi-insulating silicon wafer at \( x = 0 \) is assumed to represent the test structure.
- Thermal balance of a semi-insulating piece of silicon wafer due to a rectangular power pulse is assessed to occur when the critical temperature is reached, where the excess carrier generated due to thermal effects causes the majority carrier concentration.

\[ \text{Analytical model:} \quad \text{energy to failure} = \text{integration of product of power and diffusivity along the pulse width and time to failure.} \]

Fig. 1 The report of energy capability of LDMOS as a function of ambient temperature data analysis

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