

## CHAPTER 5

### CONCLUSION

#### 5.1 Project Summary

In this paper, a newly design of a MEMS microrelay was designed with single pole single throw vertical switching piezoelectric actuator for uses in RF telecommunication applications. Its fixed-fixed bridge structural formed with two cantilevers is capable to be switched in low driving voltage about 7V for 2 $\mu$ m displacement distance. Its flat-to-flat contact surfaces have a good contact area and given the lowest on-resistance about 0.3 $\Omega$  with a contact force about 4 $\mu$ N. Then, its 51.537 $\Omega$  characteristic impedance of the microstrip line had given a perfect impedance matching, and furthermore it is able to be transformed into a W-band signal line by combining with another finite ground CPW and a straight coupling stubs for return loss better than -17dB from 85GHz-100GHz. After that, the mechanical path of the model was simulated and analyzed with the numerical simulations using SamCef Field\_Oofelie Ver. 5.2 FEM CAD software under piezoelectric domain. All the results showed that the mechanical path with 1080 $\mu$ m X 270 $\mu$ m footprint is functioning properly with only one mode of resonant frequency about 335.87 kHz of its beam structure. Beside that, piezoelectric actuation microrelay is well suited in RF telecommunications due to its tiny size, do not produce magnetic fields nor affected by them, and the ability of piezoelectric effect continue to operate even at temperature close to 0°K for a broad application area.

## 5.2 Recommendation for future projects

There are a serial of recommendations suggested as future potential projects for further research and development studies in order to gain a better performance and reliability design. Firstly, this design should have further complete simulations with CADs to compute its behavior and characteristic as a bimorph piezoelectric sandwich electromechanical microrelay together with its signal path. It is no harm to compare the simulation results generated from SamCef Field Oofelie with another type of FEM CAD software for verification purpose, such as Ansys. A details analyses and CADs simulation can prevent the potential failures in the development process later.

Beside that, the case studies should also consider the potential optimization in every dimension in order to gain improvement for robust design, better performances and universal applications. Sometime, the optimization or modification is also needed to suit into a specify application. So the possible optimization discussed before at previous chapter should be used as references in the future relevant projects. However, if for innovation designs, the existing single pole single throw piezoelectric actuated microrelay may also switches to another type of topology, such as single pole double throws.

Other than that, dual actuation modes are also applicable for better performance, such as combining the piezoelectric actuation method with electrostatic method. Since piezoelectric materials are used for both sensing and actuation purpose. So, the generated electric charge when they are under mechanical stress of its direct piezoelectric effect may also be used for the second actuation mode. However, this direct effect must be generated from different layer of piezoelectric material instead of the one used for the actuation.

The last recommendation is in developing of the device in order to fabricate a real device for further studies. Therefore, microfabrication of MEMS technology must be concerned together with it packaging technology. A proper process planning and material selections tend to increase the yield percentage and minimize it cost charging.

### 5.3 Commercial business appraisal

This business appraisal was done from point of view for a fresh graduate who is willing and plans to become an entrepreneur as a beginner. So this appraisal was setup with consideration of little capitals and a weak financial background. So, the final year project outcomes were used and turn to be a business potential as an initial step toward success. According to Fione Tan the CEO of eOneNet an internet marketing company, anyone with basic IT skills, passion and commitment is possible to run an internet business with little capitals [28]. Furthermore, e-business is the one with the lowest barrier of entry but the highest of leverage, so it will be used as the format to market our products or services.

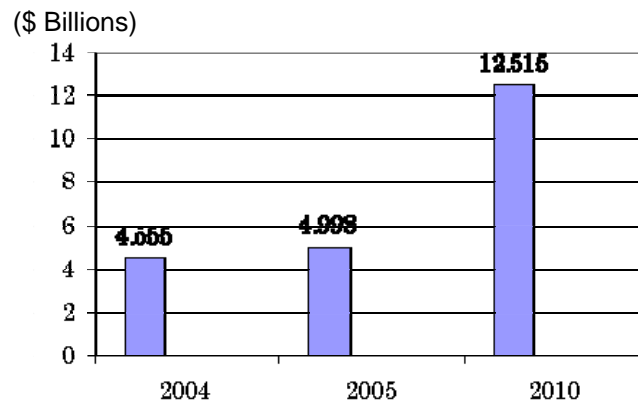
#### 5.3.1. General Idea

MEMS technology will be the core element in planning for this first business success. This business will be based on the basics on developing the MEMS technologies instead of just commercialize its ready made devices. It's including continuing researches, publishing, design, modeling and simulations. These will be enabled with the concept of e-business or e-commercial as the initial step. So this kind of business will be more likely as E-library, E-publisher, E-consultant and a fab-less virtue design house.

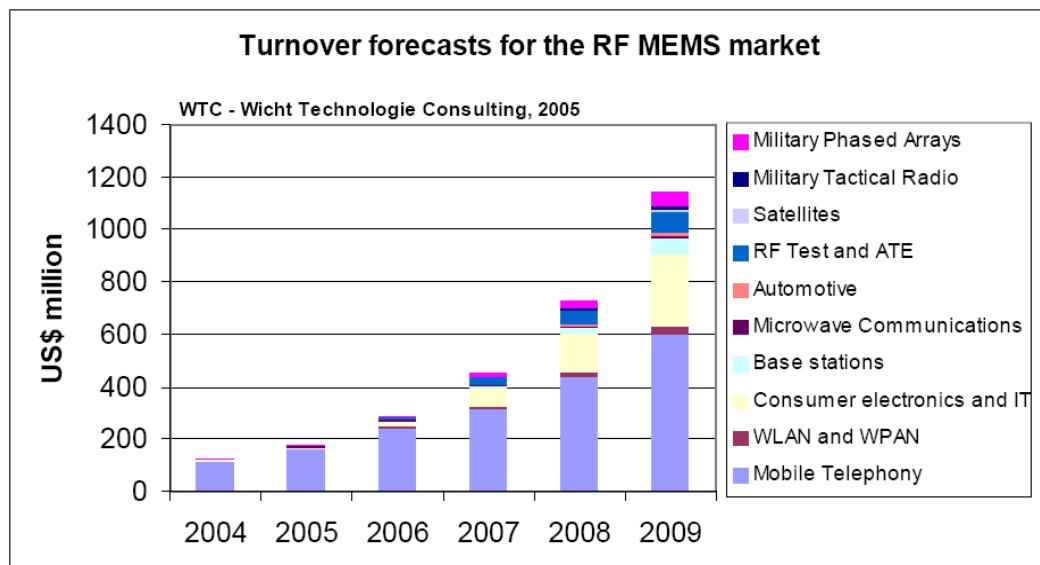
Then, the outcome results of the final year project will also be part of it contribution toward the success. It will be commercialized based on the journal or research papers, and design patent. Beside that, the methodologies used and it literature reviews also can be published as e-books for public references. Next, the same concept will also be applied to others relevant R&D outcomes to convenient our clients or users with it multiples choice to select.

MEMS technology was chosen as its core element because it is best described as an enabling manufacturing technology as opposed to an industry. The adaptation of

MEMS technology to a variety of new products offers tremendous market potential [29]. According to an updated technical MEMS Market research report [30], the global market for MEMS devices and production equipment was worth an estimated \$5 billion in 2005, and will increase rapidly to \$12.5 billion through 2010, with an average annual growth rate of more than 20%, as shown in figure 5.0. Accelerometers have a projected AAGR of 45% between 2005 and 2010, are expected to be the second largest MEMS market segment after microfluidics by 2010, with over 22% of the market. Gyroscopic MEMS and particularly RF MEMS are also projected to gain significant market share between 2004 and 2010.



**Figure 5.0:** Global forecast of the MEMS market between 2005 and 2010 [30]



**Figure 5.1:** Turnover forecasts for the RF MEMS market [31]

Another press released on 17<sup>th</sup> OCT 2005 saying that RF MEMS will be presented as one of the next major opportunities for MEMS market to grow rapidly from \$125 million in 2004 to more than \$1.1 billion in 2009, according to a new study by German-based consulting firm WTC [31]. The turnover forecast for the RF MEMS market is shown in figure 5.1. Therefore, E-business will be the most suitable business format to globalization commercials for larger market and sources/ supplier with highest speed and least capital.

### 5.3.2. Opportunity

There are likely to have such similar ideas in the current markets trend, either in the products they are selling or in the services offered by them, or both. That why e-business is strongly recommended to increase the market possibilities and sources to everywhere of the world wherever accessible by internet. It is used to explore for any potential new markets and sources without the boundaries concerns instead of just limiting at the local competency market. Hereby, Dell Inc. is one of a good example among others who is delivering their best service and IT technology products selling around the world without any outlet or retail. They established with e-commerce as they are currently applied after many alike company selling the same type of IT products and branded product, and nowadays they still keep gaining revenues from its. The keys to success in e-business are best services, quality products and cheaper price. The most important element should not be ignored is that ability for customize, and fulfilling the customers needs. So it is possible for them to change their mind and make a switch if this is a good alternative choice with a lower cost, and it is more significant by comparing some of the cases in Malaysia, such as Malaysian Airline and AirAsia, or fixed line services provided TM Berhad and existing mobile services providers.

MEMS technology will be the best solution for most of the products since it offers a substantially higher performance with miniaturization, integrateable with other solid state circuit for better system, and cheaper price for batch fabrication production over the conventional devices. Beside that, MEMS also offers broader variety applications, from health care industry, mobile telecommunication, automobile,

aerospace Industry and etc. The concept of knowledge sharing and continuing research and development by aids of E-library and the virtue lab-less design house, enabling none stop upgrading in term of the technologies, methodologies, and creativity or innovative ideas for further improvement on new designs. Hence, more opportunities are possible to be created is nearly infinite in the sources and market all over the world. Then the cost of charges are believed will be lower since the design and the services are generated from a virtue design house and virtue world wide R&D sources.

As evident in the responses from leading executives, successful commercialization requires the application of technology to identified market opportunities [29]. This necessitates an intimate understanding of product opportunities and expertise in MEMS process technology. However, product companies may not fully realize the complexities of MEMS processing and process experts are not often established in specific product markets. Collaboration between companies and tertiary institutions and colleges with professional researchers or process expertise and those with market expertise can lead to successful and rapid MEMS product development. In other word, every expertise in this related field are needed to be met and know, and linked with a strong relationship for collaborative development. This kind of collaboration will be more easier to start from tertiary institutions with education concerns program. This kind of relationship development will then be possible to expand to others industrial collaboration with numbers of quality outcome, awards, and programs.

### 5.3.3. Resource(s)

In order to realize the idea into a real product or services over e-business, some of the resources must not be ignored even in the earlier stage are the quality internet infrastructure, IT equipments and IT expertise for setting up the first world wide web. Then is followed by the quality man power to operate and maintains the services and technical supports. After that, the most costly MEMS design tools is the CAD modeler and thin film material properties with devices and package analyzer to enable

simulations that accurately predict device performance and reduce fabrication iterations. It is to reduce the component development times and increase its reliabilities.

Most of the resources stated here are obtainable with sufficient amount of funds. It is believed to be the main factor for most of the potential young entrepreneurs. Anywhere funds can still be raised from SME bank loans or capitals investment from third parties investor, but the possibility will only reserve for good business plans with a brilliant and high potential business.

#### 5.3.4. Implementation

However, an assumption was made for lack of funds in setting up the business completely within a short duration for quick establishment. So, this plan is divided into two phase. First is to start a e-business to cover E-library and E-publisher, and then E-consultant and a fab-less virtue R&D design house will be continued in the second phase once having the sufficient funds.

For our first MEMS business appraisal to work up the E-library and E-publisher, some collaborations and programs will still be needed in order to gain the sources. First, it will be more focus in setting up the fundamental of the e-business with the limited funds and step by steps developing afterward. A webs site is like a virtue branch of the physical business, so must grad a good domain name for branding and marketing purpose. After that, is to develop a simple but professional web site. The web site must include a main page for the welcome page and a main menu with navigation menu that makes it easy for visitors to find what they want. Fast loading speed of the web site is much important to keep the potential users and prevent them from click away. Then, the unique selling proposition of the services and products will be set as the headline to attract visitor become the potential clients.

Since the E-library is the knowledge sharing center, so it must be developed first to extract users, and following by the E-publisher for papers publishing to earn revenues from its. According to Fione Tan, the e-marketing strategies must be implemented

effectively to boost up the traffic and sales, such as build online membership and delivering free news letter via email [28]. For our case, the online membership can be implemented for both e-library and e-published with some freebies to attract their attention such as membership discount rates or some free gift. Of course, the payment mode must be convenient enough and is accessible through credit card online payment with the aids of e-commerce merchant account.

Publicity thru some internet search engine like Google and Yahoo can easily start or expand the business globally. So the key success in the business into the global market one is to get the top ranking in search engines [28]. Other than that, it still can be achieved by applying email marketing for lower cost charges. Integrate email marketing [28] to increase the sales instantly with advertising campaign by working out a special promotion include the viral marketing elements to induce the recipients to refer their friends with some incentives. Furthermore, design an HTML email template could be applied for better response.

The next stage, the business fundamental will be strongly formed by involving some collaborative with the tertiary institution with some related programs. The collaborative with others companies and some none academic institution will be build afterward. Once, the E-library reach a sufficient amount of database and information, the E-consultant will be developed with the aids from either self expertise or external profession personnel.

For this initial stage, the design works or projects will be performed by involving some joint venture projects or research at the tertiary institution for expo or academic purpose. After everything is stable and gained sufficient revenues from the publisher then only will be switched to our main core in design and simulation by setting up a virtue lab-less design house for MEMS. However, the business and company structural will be developed in the same time while running the first phase in order to smooth the business operation and have a perfect matching on it to grow together.

Rapid growth and commercialization of MEMS requires equally rapid product development [29]. While tremendous market opportunities exist for a variety of MEMS devices, rapid development has become a leading commercialization challenge. The



most critical challenge to MEMS product commercialization was the length of product development. Reasons for the lengthy development time include a historic MEMS technology push, a lack of process expertise, and manufacturing obstacles. MEMS technology for technical excitement versus commercial potential may explain lengthy development as technology development leads application identification. Other challenges in R&D and manufacturing contribute to extended product development. Process expertise and material control were identified by 87% of companies as the major obstacles in MEMS research and development. To achieve MEMS market potential technology commercialization strategies and programs that resolve prolonged development are required.

#### 5.3.5. Conclusion

As the conclusion from the commercial business appraisal for this MEMS potential market through the e-business model, a company is needed to be setup due to confidence the sources and users. It's also very important to have a self brand in building the network and collaborative with third parties. According to the business appraisal, I felt that it is very hard and difficult to commercialize the service and product by creating a newly form company with limited fund, but it is still possible to bring it into realistic with smart and hard works. Finally, I'm confidence that the MEMS highly potential market will be able to bring the idea of the integrating of MEMS technology and e-business toward it success with a proper planning. Then it sustainable is very dependence on the management, marketing and technical support later.

#### 5.3.6. Recommendation

A partnership company is suggested due to have more sufficient funds and quality man power to operate the business. Collaborative with others parties are strongly recommended to build up a bigger network and strong relationship for continuing research and development.