CHAPTER 5

SUMMARY, RECOMMENDATION & COMMERCIALIZATION POTENTIAL

5.1 SUMMARY

A microfluidic capacitor is successfully fabricated. The design is evidential to be true and practical for production. Along the way, many pre-fabrication tests were carried out to verify each step to ensure the quality of the process is retained on the real wafer. Many findings were obtained along the way through these pre-experimental works.

One problem confronted during the pattern transfer is peeling photoresist from the wafer surface. This proves that for such miniscule dimensions, the strength of adhesion is lower, thus causing the peels under slight forces like developer's and DI water's flow currents. This is not a problem in the case of the reservoirs and electrodes as they were bigger in area, thus providing better adhesion onto the wafer surface. To prevent this problem, Hexamethyldisilazane (HMDS) should be coated primarily before photoresist coating. This would enhance the adhesion of resist to the wafer. In this project, due to the limitations in supplies of such chemicals, a short hard bake for approximately 30 seconds is done. However, this step was not of much help.

Reactive ion etching for silicon etch requires silicon dioxide or silicon nitride as mask. The etch selectivity between the mask and silicon is low since most of the reactions are physical due to ion bombardment and less chemical reactions. Hence, to etch 10μm trenches, there is a necessity for at least 10μm of mask. This mask has to be deposited as it would take too long to thermally grow them. Deposited silicon dioxide and silicon nitride are porous which leads to a weak layer. Thus, a thicker layer is

necessary. Aluminium is not an answer for masking in RIE as it reacts with the CF_4 components, producing residues that are impossible to be stripped.

During photolithography, if aluminium is the surface below the resist, part of the aluminium gets etched away by the developer. One of the active ingredients in the developer is phosphoric acid which also reacts with aluminium. This posts a problem during developing. There is no room for rework of pattern transfer after one development as part of the aluminium is etched. To avoid this, the alignment of the mask is critically important. There is no room for a minor misalignment. The mask must be precisely aligned before exposure. Failure of doing this may require stripping of aluminium layer and re-deposition.

KOH (potassium hydroxide) is an anisotropic etchant unlike other wet etchants. At 60^0C at 25% concentration a good selectivity between silicon dioxide and silicon is achieved. However, the etch profiles may not be smooth. At 80^0C, the etch profile is better but the selectivity between silicon dioxide and silicon become lower.

5.2 Recommendations for future Projects

A lot of delay was experienced while waiting for the masks to arrive. This matter may seem minor, but it consumed so much of precious fabrication time, almost 3 months. It is recommended that when a task is assigned to a third party, continuous follow up and need for prompt feedback is essential. When the actual process is started early, more time is available to tackle arising problems.

The size of the device is not a big matter but the sizes of the channels are. Small scale designs are difficult to be transferred in to the wafer. Certain areas get etched faster than the others. This posts a tremendous problem. This problem can be avoided by violent agitation of the developer solution to create turbulence. However, the adhesion of photo resist on silicon surface is no strong enough. In has a high tendency to peel off in

such agitations. A layer of adhesion promoting HMDS should be coated first before photo resist.

To etch silicon, RIE would produce a cleaner surface (without potassium ions contaminant) and smoother profile. Aluminium is not a suitable mask for RIE. It is recommended that thermal oxide is grown first followed by Plasma Enhanced Chemical Vapour deposition (PECVD) silicon nitride or oxide to obtain more than 10μm thick mask. The mask would be etched with low selectivity between mask and silicon. There may be some residual depositions that may be very difficult to remove. A thick layer of mask may be an answer to this.

5.3 COMMERCIALIZATION

5.3.1 General Idea

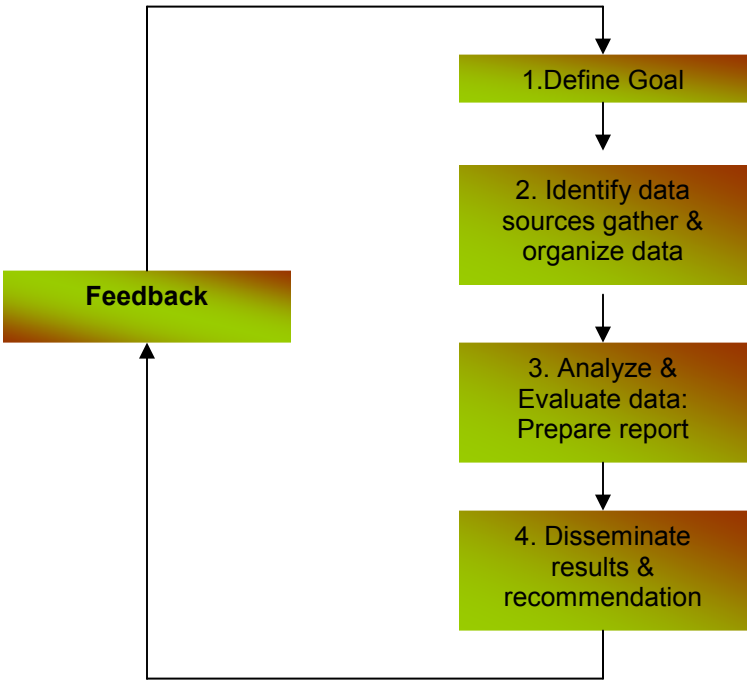

Figure 5.1: Intelligent Marketing Process

Microfluidic capacitor is a spark of innovation to the conventional capacitor, where fluid is used to substitute the insulation between two electrodes. Various types of liquid can actually be used in this capacitor which attributes to its vast applications in a wide spectrum of field. With the interest and research on microfluidic moving at a furious pace, this device has a dynamic potential to be the next gear in MEMS technology thrust.

This product has a great marketable potential. Mass production of the device using the designed characteristics and process recipe will further help reduce the cost of production, thus making it available at a low-cost. The magical combination of quality and purchasing cost make up the golden rule for marketing. The simplified process flow and low consumptions of material makes this system suitable for low capital entrepreneurship. The microfluidic design is also compact and requires minimal operation cost. Overall, the magical stigma is achieved.

Microfluidic capacitors have vast potential in the field of Biotechnology, Medicine, Chemistry and Electronics. The extensive versatility of this device can drive all the fields mentioned to a new level of technology. The quest to unveil the human genome code now has a ray of hope with the dawn of microfluidic technology. Cheaper research cost can lead to more works being carried out to aid these experimentations.

The micro dimensions used in this device requires lower volume of consumables due to its narrower channels. This also means lower consumption of expensive and rare reagents. Again, this is a tremendous opportunity for reduced cost applications. The flow within the channels is due to physical dynamics, capillary reaction and Electric Double Layer. Hence, there is no necessity for an external flow inducing device like pumps.

Now, being the peak era of technology, advanced communication technology has brought us another step closer to living in globalisation. Internet is made accessible at most corners of the world. Marketing via this channel would be of great advantage to achieve sales.

This microfluidic capacitor could be sold online. Detailed information, characteristics and flexibility in design based on applications will all be available online. Main targeted customers would be research institutes, universities, the medical and chemistry laboratories and Food industries who would require a variety of application needs that could be promised with a solution by microfluidic capacitors. The purchase of the product comes with free consultancy service. The device can also be custom made to suit the different needs of the customers. For instance, the chemistry laboratories may need materials that could withstand strong chemical reactions and the medical departments will need longer channels. If their specific needs are fulfilled, the microfluidic capacitor would have better marketability.

5.3.2 Opportunity

Currently in the global market, it is not easy to purchase or custom make a microfluidic capacitor. This sort of product is not readily available for small scale users due to their high manufacturing costs. Purchasing them would require a tremendous work load and would be time consuming. Custom designing the device would also require a combined effort by many departments before production. The market price is high to cover the big expenses involved in production.

Figure 5.2: Product Concept

This design has remarkable design that can be changed immediately without much time. The processes involved in producing the complete device from a bare wafer are economic and simple. Less processes also mean faster fabrication period and cheaper production cost. So, the waiting period from purchase order to deliver would be extremely fast. With online purchasing, this process would be further enhanced.

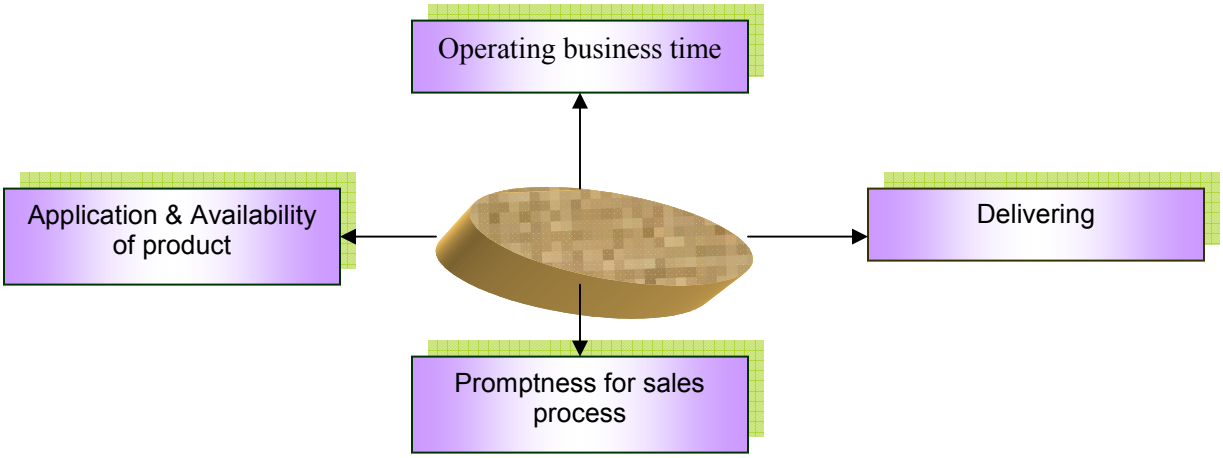

Figure 5.3: Time Factor

Why move from their conventional supplier to this version of a microfluidic capacitor? This is among the most frequently asked questions among the current users out there. The first reason would be the cost. If another company could offer their product at a lower cost without compromising on quality, why not change? It is an opportunity for the institution to cut down their cost. The product is guaranteed of its quality and it is definitely a much cheaper option. Providing better payment options like credit would be an added advantage.

With the product easily available online, the purchasing can be made with no haste from the desktop of the purchasing department in their office. Without having to leave their doorstep but to have delivery made to them is the next marketing trend. No hassle in filing troublesome documentations involved. Payments will be made upon order online using credit card services.

Some improvements can be made on the product to make it more attractive. The quality of the materials used could be of a superior version for better yield and durability. A more stringent quality control regulation can be fostered to make sure that the products work efficiently. For a single use device, this feature would not be necessary. But for long term use, durability is paramount. Packaging would also improve on its reliability and aids handling. The product becomes more durable too.

To make this a reality, many areas would com into play. A legal advisor is necessary to monitor the marketing activity and as advisor in legal matters. Questions on warranty issues will also be handled by them. A marketing institution has to work on publicity, online marketing and creating marketing strategies to increase the revenue. They have to meticulously plan in detail the areas suitable for marketing and constantly scrutinize the economic state of a certain marketable arena.

On the technical side, a fabrication company has to be given the contract for producing the devices. Several companies will have to be surveyed and their quotations reviewed. The company with the best bargain and guaranteed quality will be selected. A design house will be selected for mask designing on 12 inch wafers to mass produce the microfluidic capacitors. Looking for such companies would not be a problem as there are many avenues in Malaysia that caters to this.

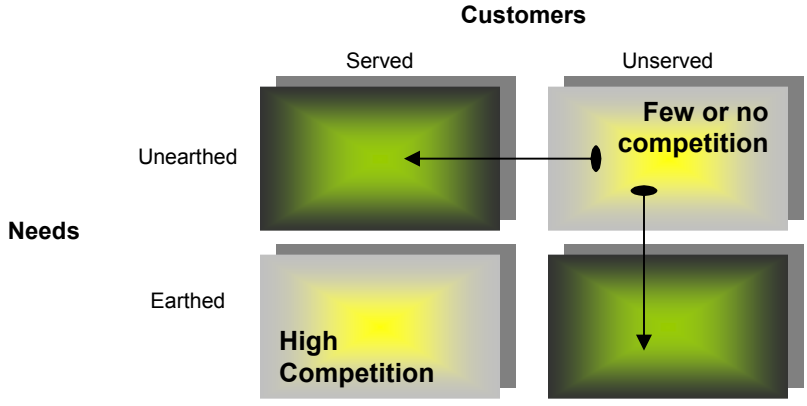

Figure 5.4: Competitor

Competition would definitely be a threat to this entrepreneurship. However, it is best to reach to areas where there is a dire need for the device and also where the needs are not fulfilled. There would be a bigger purchasing capacity in such avenues. Hence, selection of where the product will be marketed is also an important criterion in setting up a business. When the market becomes saturated (more supply than demand), the market belongs to the customers. Marketability of the product thus declines. Figure 5.5 is evidential of such scenario.

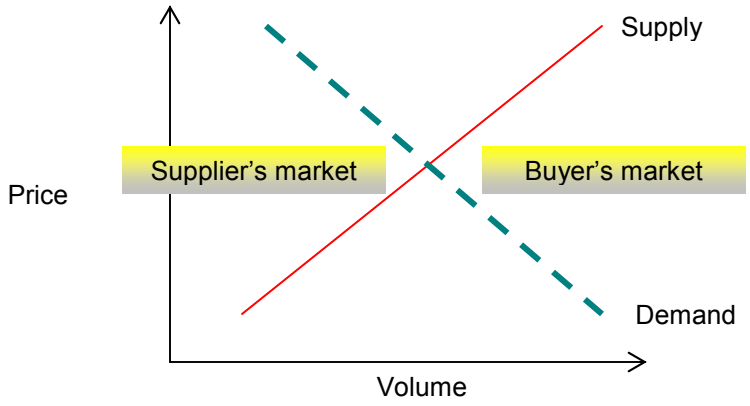

Figure 5.5: Market Analysis

5.3.3 Resources

To make this product a reality, many resources have to be gathered. The first element is capital to fund the designing and fabrication of the device. Being an undergraduate and funding to start this mega-project, it would be wiser to assign different companies to manufacture the product. It would be practically impossible start up a clean room and purchase the equipments necessary without adequate working experience in this area. Besides, the cost to start up such facilities would be huge. Without proper paper proposals, it would no be possible to obtain loans for such start ups.

As a beginner, I would handle the business management, marketing and design areas of the production. The actual production will be branched out to companies that already possess necessary facilities. If the business revenue increases, the turn over can be rotated for further investment on research works for more products, discrete and integrated can be done.

For a start, since the fabrication task is branched out, the business will centre at home, all I would need is a computer and internet service to access orders. The different needs of each customer may require some changes on the original design of the microfluidic capacitor. Designing can also be done from home. Increased customer's needs may require more man power to handle the purchasing and selling. A product engineer may have to be hired to handle newer designs. On the other hand a process engineer with sound knowledge in microelectronic processes has to set the recipe necessary for manufacturing the device.

Marketing personnel would be a necessity when it comes to publicity. This person will handle incoming orders and also be in charge of marketing the device to other areas like research institutions, and chemical and medical laboratories. A sales expert from technical background would give a good insight on the product's advantages to potential customers.

The tools needed for this business are AutoCad for mask design and TSupreme4 for process verification. When the business flourishes and there is need for more complex Integrated Circuit designs, IC design tools such as Mentor Graphics would come in handy. Licensing these softwares are expensive and is only worth for larger scale manufacturing.

The advantages of this production compared to those of the other companies are its easy accessibilities via internet and doorstep delivery scheme, free consultancy and quick custom made designs to suit individual company's needs.

5.3.5 Implementations

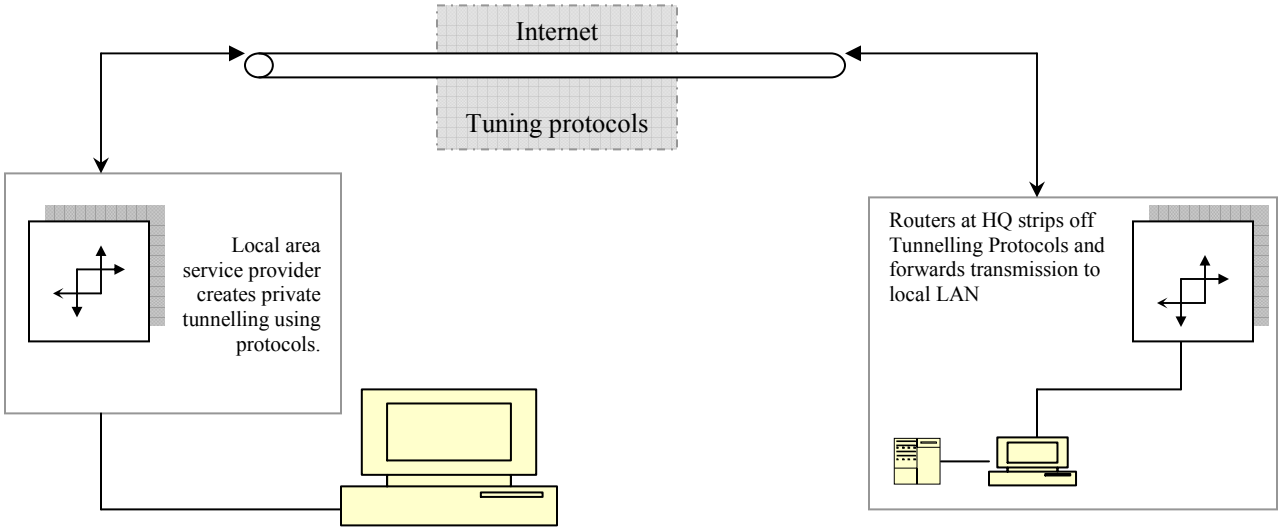

Figure 5.6: Internal Electronic Data Interchange with Virtual Private Networks

Using the internet as a channel for marketing is the new generation business technique. Via internet, the product can be marketed to the global world and made available for international customers. Figure 5.6 shows the attributes of such business links. Besides, marketing this way does not require too much capital for a start. Figure 5.7 depicts a basic construction of business organisation using the web.

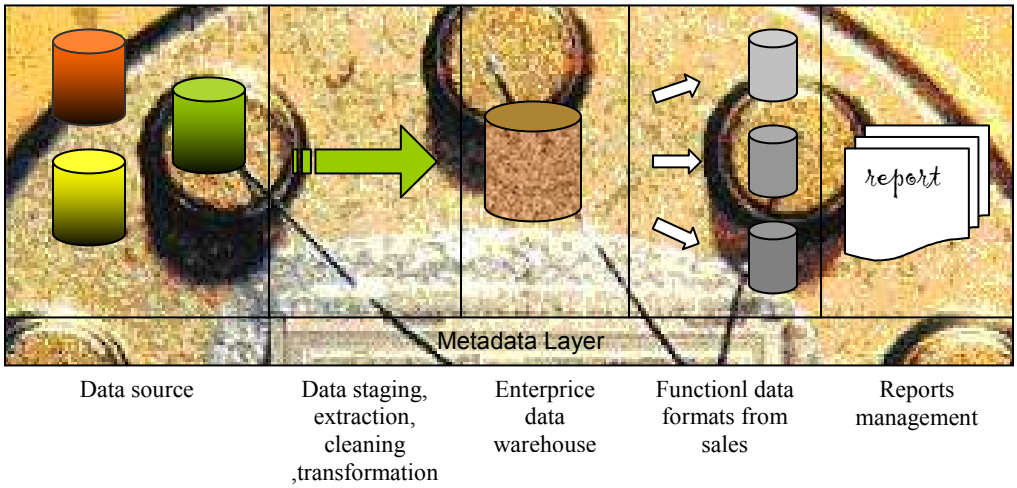

Figure 5.7: Operational Data Ware House (ODW) in the enterprise

Business world is full of mysteries. A lot of calculated and uncalculated risks may be faced along the way. But, it is about taking the challenge and being prepared to face the worst situation. One major challenge would be competition from other giant companies. These companies also hail quality and cheap products because of mass production. Besides, they have already engraved good reputation among their customers. It would be a massive failure if we fail to put forward better quality products, competent to the bigger companies.

The other possible risk in this business is computer hackers. This group of people may hack into the confidential site of purchasing and banking which would deteriorate the belief of customers. This can be avoided by using highly efficient encrypting tools that would not allow unauthorized people from accessing the financial and credit matter of the company.

5.3.6 Conclusion

A company has to be set up as an avenue to manufacture and market this microfluidic capacitor. The company will hold the reputation of the product or the branding aspect of the capacitor. A brand is a symbolic embodiment of all the information connected to a company, product or service. A brand serves to create associations and expectations among products made by a producer. The company plays the role of the intermediate or ambassador of the product.

Brand and branding equities have become components of cultural economy. Nowadays, it is considered cultural accessories and personal philosophies. Small enterprises are unable to reach further into the horizons of business and marketing without proper branding. With a registered trademark, this product will be able to compete with other leading brands.

The fall and flourishing of the company depends on the marketability of the product, the revenue cycle that keep the company going and the implemented marketing strategy. If all these reach equilibrium, the company will prosper. The sustainability of the company is very dependant on the revenues or income of the company and the financial reserves. With promising potential and wide application of the product, I am confident of the marketability and long term sustainability of the company.

This part of the project, the commercialization aspect of the product created enthusiasm to further enhance the quality of the product and to be an entrepreneur or technoprenuer in this area. With extensive study and analysis on marketing strategies and marketability, I am convinced that the company has a bright future in achieving sales targets and continuously work on the improvement of the quality and diversity of production.

5.3.7 Recommendation

To start the business and gain experience in the area of business and commercialization, it is advisable to always earn a partnership with established companies. This would be an added advantage as facilities and resources would be available for use whether in research and development or even production. With that, the investment on the product development and marketing would be proportionally shared out. The existing customers of the company would be the first candidates for the new product.

5.3.8 Strengths, Weaknesses, Opportunities and Threats

Table 5.1: SWOT Analysis

SWOT	Description
Strengths	• Advantage of product: *smaller size, cheaper, easy purchasing; via online marketing, free consultancy on use and applications, custom design for enhanced suitability for specific applications.* • Flexibility in design compared to other companies • Cheap start up cost: production delegated, only handle marketing and designing. • The additional benefits like the above are a plus point that would threaten similar products from other companies
Weaknesses	• Low funding to jump start on a new company as initial production cost is tremendously high • Reliability of the product is not tested; A thorough reliability scheme has to be set and each product must pass through a thorough quality check before shipment • New company, no market reputation compared to established enterprises.
Opportunities	• This version of the microfluidic capacitor has many advantages • Cost of mass production is low. • Online marketing involves less capital investment and promises a wider market • Increasing demands for research and development in the fields of environmental studies and biotechnology • Government's policy and incentive to small and medium enterprises are supportive. • Higher demands for high technological devices for research in the medical field for global health
Threats	• Lack of experience in online marketing and mass production • Fast moving technological trends with innovation on current products • Multiple device integration within a single chip