Institution: Hong Kong Baptist University

Unit of Assessment: Physics

Title of case study: Ultra-hard, Anti-scratch Thin Film

1. Summary of the impact (indicative maximum 100 words):

Prof Cheah Kok-wai of the Department of Physics and his research team developed a low-cost, ultra-hard and anti-scratch sapphire thin-film technology. They won the Grand Prix, the Special Award from the Romanian Association for Nonconventional Technologies and a Gold Medal (with Judge Commendations) in the category 'industrial processes' at the 44th International Exhibition of Inventions of Geneva in 2016.

Prof Cheah founded a start-up company Cathay Photonics Limited (CPL) in 2014 to commercialise the technology. 25 patents were filed with 10 granted non-provisional patents contributing HK$ 1,080,000 towards the IP Rights.

2. Underpinning research (indicative maximum 500 words)

With extensive experiences in photonics and optoelectronics industries [3.1] [3.2], Prof Cheah led his research team, including Dr. TAM Hoi Lam and Dr. LI King Fai of HKBU, to establish Cathay Photonics Limited (CPL), and developed a patented technology for a transparent ultra-hard and anti-scratch thin film. The thin film can be deposited onto substrates such as quartz, fused silica or toughened glass. This combination is better than a bare sapphire substrate because the latter is hard to scratch but brittle. In general, the harder the material is, the lower its toughness (i.e. the ability of a material to absorb energy when impacted). Therefore, using the soft substrate with hard thin film coating is an ideal combination. The anti-scratch property can be achieved by applying the hard thin film coating. Hence, the combination of thin film on quartz, for example, creates a cover glass that is lighter in weight, has a hard top-surface and costs less. The potential applications of this cover glass include mobile phone cameras, smartphones, tablets, spectacles, hybrid notebooks and watches.

After the formation of CPL, six postgraduates from the Department of Physics were employed; four of them were from the research team of Prof. Cheah, and two were graduated from the department's M.Sc. Program, Green Technology. An alumnus from the Department of Physics was recruited to become the general manager; he holds a Ph.D. (from the department) in optoelectronics and had worked in a start-up company in China.

The granted patents in US and Taiwan protect the key research findings which provide the technological advantage of CPL [3.3][3.4]; all the team members were employed by HKBU during the qualifying period for the generation of the underpinning research. The patents covered two most common fabrication processes for the thin film deposition; these two fabrication processes could also be scaled up for industrial mass production since the relevant manufacturing equipment is readily available in industry. The patents also covered numerous substrates being used commercially and the application could be extended to non-transparent and/or flexible substrates.

Growing single crystal sapphire is time consuming and technically very challenging for large size substrates (i.e. greater than 6 inches). So, the production yield of sapphire is fairly low due to the two critical criteria of feasibility and repeatability and long fabrication times cause high production costs (i.e. higher than US$40 per screen). Compared to existing technology, the anti-scratch thin film produced by CPL is lightweight yet tough and has a high optical transmission. Also, it costs less to produce and requires less processing time. The deposition process is an industrial standard process that can be adopted with minimum development time. Importantly, this technology can be adopted by industry without further investment in new equipment and facilities.

3. Reference to the research (indicative maximum of 6 references)

Patents:

3.1 **Cheah K.W.**, Li K.F., Tam H.L., Lam W.Y. & Lee K.S. "Sapphire Thin Film Coated Substrate". US Patent No. 9,695,501, granted on 4 Jul 2017.

3.2 **Cheah K.W.**, Li K.F., Tam H. L., Lee K.S., Li G.X., Lam W.Y. & Chan Y.W. "Sapphire Thin Film Coated Flexible Substrate". Taiwan Patent No. I574840, granted on 21 Mar 2017.

3.3 **Cheah K.W.**, Li K.F., Tam H.L., Lee K.S., Li G.X., Lam W.Y. & Chan Y.W. "Sapphire Thin Film Coated Flexible Substrate". US Patent No. 10,072,329, granted on 11 Sep 2018.

3.4 **Cheah K.W.**, Tam H.L., & Lam W.Y. "Sapphire Thin Film Coated Substrate". US Patent No. 9,932,663, granted on 3 Apr 2018.

4. Details of the impact (indicative maximum 750 words)

Sapphire is the second hardest material after diamond. It is transparent; therefore, it is an excellent material for scratch resistant application in displays. Sapphire glass would provide smartphones superior scratch resistant screens. However, it is a huge challenge and costly to produce large surfaces of single crystal sapphire for reasons mentioned in section (3) above.

With extensive industry engagements over the years, Prof Cheah Kok-wai of the Department of Physics led a research team that developed a low-cost, ultra-hard and anti-scratch sapphire thin-film technology. They had been investigating aluminium oxide nano-structures in earlier projects. Therefore, the research team has acquired in-depth understanding of properties of aluminium oxide. They turned their attention to using nanometer-thick aluminium oxide films for anti-scratching applications. The project was initially supported by the annual research/teaching budget of the department. The process was patented and funded through the university's Knowledge Transfer Office to commercialise the technology. Thus, he founded a start-up company, Cathay Photonics Limited (CPL), with the aim to apply this technology to coat electronic devices such as watches, tablets and smartphones. This patented technology is lightweight and cost effective. The enhanced surface hardness extends the operational lifetime of the products, reducing replacement cost in terms of hardware replacement, manpower and operational downtime. It is estimated that operational lifetime of the products can be extended by at least 1.5 to 2 times, reducing downtime and operation cost. Furthermore, the deposition of

sapphire thin films used Physical Vapour Deposition methods such as sputtering and e-beam. They are commonly used by the relevant industries. Hence, this technology can be easily adapted for mass production, saving cost and manpower training by as much as two thirds of normal cost/time for new technology adaptation.

Based on the technology potential, CPL was awarded Technology Start-up Support Scheme for Universities (TSSSU) grants from the HK Innovation Technology Commission in the years 2014-15, 2015-16 and 2016-17 [5.1]. The team has applied the technology on several products, building a customer base and working with industrial partners for technology commercialisation. The team has also increased their patent portfolio over these years. 25 patents have been filed and 11 are non-provisional patents in the USA, Japan, Taiwan, China and PCT.

During the incubation period made possible by TSSSU, CPL attracted angel funding support from Radiant Venture Capital [5.2], a Hong Kong based VC company. CPL received venture capital in 2014-19 to support their pilot production collaborating with mobile cover glass suppliers and a watch surface manufacturer. At present, CPL's market value is over US$100 million.

Prof Cheah and CPL received the Grand Prix International Invention Award, Special Award from the Romanian Association for Nonconventional Technologies and a Gold Medal (with Judge Commendations) in the category 'industrial processes' at the 44th International Exhibition of Inventions of Geneva. [5.3].

Besides, Cathay Photonics Limited was crowned champion in the World Elevator Pitch Competition 2017. The company beat 99 other finalists from across the globe and was awarded an investment prize worth US$140,000. Following these achievements, several Hong Kong and overseas media outlets reported on the invention and its accomplishment. [5.4] [5.5] [5.6] [5.7] [5.8] [5.9]

Cathay Photonics Limited has, so far, signed three product development contracts and formed one joint venture (JV). One of the companies is from Singapore and we are developing anti-scratch glass for supermarket bar-code scanners and travel document scanners at ports of entry. The second product development contract is with an international technology broker (Japan-based) developing anti-scratch coatings for foldable displays; samples have been provided to a Korean customer (Kolon). It passed the first stage performance requirement with a HK$500,000 payment and moved into the second stage development, at the same time commencing sample preparation for the Japanese customer (Sumitomo). These two customers supply more than 90% of the flexible substrates in the world, so we are in a position to become the dominant anti-scratch supplier in the world. The third product development agreement is for an integrated anti-scratch+anti-reflection multi-layer for watch/camera application and is signed with a local HK supplier of watch parts to European and Asian brands.This project is entering into mass-production stage. The JV partner is a Hong Kong based watch marketing company that has strong connections with well-known watch brands in Europe and the USA, developing anti-scratch coatings on metals for watch applications. A product development agreement was signed

by the JV company with one of the major watch suppliers. These four customers reflect the potential broad application of the technology and its global attraction.

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 **Cheah, K.W.** (2014-17). Chairman of Cathay Photonics Limited, Technology Start-up Support Scheme for Universities (TSSSU), Innovation and Technology Commission, the Government of the HKSAR: https://www.itf.gov.hk/l-eng/TSSSU/HKBU/TSSSU_HKBU_14_05_1_E.pdf

5.2 Screen capture of the comments from the officials website of the International Exhibition of Inventions of Geneva: http://archive.is/2017.05.23-044031/http://www.inventions-geneva.ch/en/home-en-gb/31-programs/100-preize-list

5.3 Letter of testimony from Radiant Venture Capital Limited.

5.4 Oriental Daily (Hong Kong), 21st April 2016, "浸大藍寶石納米超硬薄膜　奪日內瓦發明大獎"

5.5 Screen capture of the comments from the officials website of the Innovation and Technology Commission: http://archive.is/2017.05.23-044310/http://www.itc.gov.hk/enewsletter/160601/big5/TSSSU_technology_start_ups_celebrate_their_success_in_bringing_R&D_results_from_campus_to_real_world.html

5.6 MingPao (Hong Kong), 17th April 2016, "浸大研發納米「鐵甲玻璃」 製手機屏幕可抗跌抗刮花 瑞士發明展獲最高榮譽大獎"

5.7 GMA News online (Philippines), 16th April 2016, "Hong Kong prof's sapphire-toughened screens win invention prize"

5.8 L'Hebdo (France), 15th April 2016, "Un procédé pour durcir les surfaces en verre primé à Genève"

5.9 PR Newswire, 14th November 2017, "科技園電梯募投2017 大學科研贏百萬資金"