

Research Assessment Exercise 2020

Impact Case Study

University: City University of Hong Kong

Unit of Assessment (UoA): 14 - Mechanical engineering, production engineering (incl. manufacturing & industrial engineering), textile technology and aerospace engineering

Title of case study: Development of Zero-Defect Coating Technology for the Watch Industry

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

The watch retail-and-manufacturing is an important economic pillar in Hong Kong and this work solves a long-standing problem of the industry. For aesthetic purpose, gold plating is often applied to the timepieces with other metals such as copper and silver to achieve popular colours such as 'rose gold' and 'pink gold'. However, such plating rapidly loses its desirable brightness and colour due to oxidation or corrosion. Responding to an industrial request, this work develops a transparent barrier that protects the surfaces from the environment while retaining the original colour. The work is much welcomed by the industry and they provide 10% of the project budget.

2. **Underpinning research** (indicative maximum 500 words)

It begun with collaboration between two departments

The inception of the Advance Coatings Applied Research Laboratory (ACARL) begins with its founder, went to a tribology (à la friction, wear and lubrication) conference in UK in 1997 and he discovered half of the conference was hack jacked by thin film physicists who spoke a completely different language from normal engineers. When he came back from the shock, he approached the Applied Physics Department to seek for help and it resulted in a collaborative research in diamond films deposition on steel. The pilot work was funded by City University of Hong Kong (CityU). Our first paper on DLC coatings was published in 2000 [1]. At the time, most of the experimental work were carried within an AP research laboratory (COSDAF). One project leads to another and the rest, as they used to say, is history.

A new coating research laboratory

ACARL was set up in MEEM Department (now Mechanical Engineering Department) in 2000 with a HK\$10M grant (project title: Diamond Coatings for Hong Kong Manufacturing Industry) from the Innovation and Technology Commission (ITC) and sponsorships from local industries. At the opening ceremony in 2001, Mr. Francis Ho, JP, Commissioner for Innovation and Technology, stressed the significance of the laboratory for its involvement with the "foundation" production industry in Hong Kong and the Pearl River Delta Region. The initial objectives were mainly to promote the use of advanced coatings in Hong Kong and also to provide coatings services to local industry when required. To do these ACARL had brought in established coating technology from renowned coating suppliers and installed industrial size chambers ready for making solid lubricant coatings and hard coatings [2, 3]. The main facility occupies an area of approximately 110m² and is also supported with a range of surface characterization and mechanical testing equipment, which are essential in the development and application of surface coatings. Later, the research team received a second ITC grant of HK\$7.3M to carry out R&D work in hard nanocomposite coatings [4, 5]. The work gives HK industry a new cutting edge in applying the technology in manufacturing and to become more competitive.

Close liaison with the industry

Right from the beginning, the research team has emphasized itself as a meeting place where the industrialists can talk to the researchers regarding coating application and development matters. To this end, the team has recruited full time staff to promote the use of coatings by means of organizing

workshops, seminars, company visits and participating in trade shows. The research team also carries out coating trial, through these companies have started to use our services constantly and a good reputation is recognized by the industry. To meet the ever-changing challenges from the industry, the team has invested a great deal of resource into the research of thin films and has therefore accumulated a vast array of expertise in the coating area. Beside contact research works from industry, in 2012, the team was approached by the Federation of HK Watch Trades & Industries regarding their longstanding-industry-wide surface oxidation problem. At the time of writing, the team has solved the problem and completed two phases of R&D work and the outcomes are (i) an industrial deposition prototype has been built and, (ii) related patents are pending for approval [6].

3. **References to the research** (indicative maximum of six references)

- 1) K.Y.Li, Z.F.Zhou, C.Y.Chan, I.Bello, C.S.Lee, S.T.Lee, “Mechanical and tribological properties of diamond-like carbon films prepared on steel by ECR-CVD process”, *DIAMOND AND RELATED MATERIALS*, vol. 10/9-10, pp. 1855-1861, AUG 2001.
- 2) K.Y.Li, Z.F.Zhou, I. Bello, C.S.Lee, S.T.Lee, “Study of tribological performance of ECR-CVD diamond-like carbon coatings on steel substrates, Part 1. The effect of processing parameters and operating conditions”, *WEAR*, vol. 258, pp. 1577-1588, 2005
- 3) Z.F.Zhou, K.Y.Li, I. Bello, C.S.Lee, S.T.Lee, “Study of tribological performance of ECR-CVD diamond-like carbon coatings on steel substrates, Part 2. The analysis of wear mechanism”, *WEAR*, vol. 258, pp. 1589-1599, 2005
- 4) Z.F.Zhou, P.L.Tam, P.W.Shum, K.Y.Li, “High temperature oxidation of CrTiAlN hard coatings prepared by unbalanced magnetron sputtering”, *THIN SOLID FILMS*, 517 (2009) 5243-5247
- 5) P.W.Shum, Z.F.Zhou, K.Y.Li, “Friction and wear reduction of hard TiAlSiN coatings by an integrated approach of laser surface texturing and high-energy ion implantation”, *Surface and Coatings Technology*, 259 (2014) 136-140
- 6) K.Y.Li, Z.F.Zhou, P.W.Shum, “Homogeneous and Transparent Protective Coatings for Precious Metals and Copper Alloys”, US Patent Application Number 14/876, 156, filed on OCT 2015.

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

Contract research works

Over the years, the team has served different companies in terms of coating R&D support work. The companies include renowned ones such as General Motors, ASM Assembly Automation Ltd., Johnson Electrics, SKF and so on., The team has carried out the following contract research successfully during the assessment period:

- 1) Feasibility Study of New Antibacterial Coatings by Physical Vapour Deposition (PVD) Methods on Stainless Steel Substrates (approval date: May 2016). The results of the R&D have resulted in a series of new antibacterial consumer products.
- 2) Improvement of Mechanical Properties and Oxidation Resistance of AlCrN Based Hard Coatings by Physical Vapour Deposition (PVD) Technique with the Addition of W and Si Elements (approval date: January 2017). By the end of the contract research, the company decided to fund the team another contract research to carry out the phase two of the project: Improvement of Mechanical Properties and Oxidation Resistance of AlCrN-based Coatings (approval Date: July 2019)

R&D work to solve a longstanding manufacturing problem for the watch industry

The watch retail and manufacturing industry has been one of the most important economic pillars in Hong Kong for many years. Now Hong Kong has become the world’s second largest watch exporter (the total value of export is more than HK\$68 billion per year). At the same time, Hong Kong is also

the largest importer of Swiss watches (more than HK\$35 billion last year). With the rapid growth of economy in China, the demand of watches is increasing rapidly, and the consumers are pursuing the brand and quality of the watch products. Therefore, to expand the domestic market becomes the huge opportunity for Hong Kong's watch industry. However, the industry is facing a number of challenges such as tough competition, RMB appreciation, labor shortage, and rising cost of raw materials, etc. In order to maintain and expand the market share, it is important to increase the productivity, upgrade the product quality, create new brand, and increase the added values of the watch products by means of technical innovations.

As precise time-measuring instruments and art decorations, it is of crucial importance to improve the service life, precision and aesthetic appearance of watch products. In particular, the aesthetic quality is one of the essential elements for high-end watches and jewelry. The surfaces of metallic watch parts, including watch cases and bands, need to be polished to a high cosmetic finish in most cases. However, scratches appear easily on the surfaces during usage. The glass surfaces are also facing the same problem due to the poorer scratch resistance. In addition, the gold-plated watches are very popular nowadays, especially for the mainland consumers. Gold can be added with small amounts of other metals such as copper, zinc and silver, etc., producing other famous colours like rose gold and pink gold. As a soft material, gold can be deformed and worn out easily under external forces. Further, when contacting with chemical substances, exhaust gases or hand sweat, the gold-plated surface layers can lose the original brightness or color owing to the limited oxidation and corrosion resistance. The wear and corrosion issues have been puzzling the watch and jewelry industries for years and remained unsolved. The associated product recall or return rate is high to say the least. In 2012, the Federation of HK Watch Trades & Industries approached the research team regarding this surface oxidation problem. With the sponsorship from 16 companies and a HK\$6M grant from ITC, this R&D work was set out to solve this longstanding industrial problem and to provide timely accessible technical support to the watch industries in the area when required.

In brief, the team designed and built a new of the CVD reactor which demonstrated the feasibility and desirability of coating actual industrial products. The success of the work can be illustrated by a subsequent ITF grant of HK\$3M (Ref: ITT/023/16GP) was awarded to the team in October 2017. Under the second phase "Public Sector Trial Scheme (PSTS)", a CVD industrial prototype machine has been built for the preparation of homogeneous protective coatings based on ionic oxides under industrial conditions. Furthermore, industrial practitioners are invited to training in using the system for their products which aims to achieve commercialization in soon future. The project is still ongoing at the Hong Kong Science Park at the time of writing.

Selected industrial sponsors in this project are listed below for reference.

- 1) The Federation of Hong Kong Watch Trades & Industries Ltd
- 2) Pino Aliprandini (HK) Ltd
- 3) Hong Kong Sen Fung Vacuum Plating Company Ltd
- 4) Glamm Holding Ltd
- 5) Salinger International Ltd
- 6) Success Time Industrial Ltd
- 7) Confi Metal Finishing Company Ltd
- 8) Dominion Watch Company Ltd
- 9) Gordon C & Co., Ltd
- 10) Hanson Metal Factory Ltd

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

- A. Letters of support from the Federation of Hong Kong Watch Trades and Industries Ltd. for Chairpersons are enclosed for reference.