

# 鎳磷合金電鍍層之內應力與磨耗研究

吳瑞文、李春穎

E-mail: 9708027@mail.dyu.edu.tw

## 摘要

鎳磷合金具有高強度、耐磨耗、抗腐蝕性與微細的組織並指出可代替鍍鎘(Cd)或鍍硬鉻(Cr)，常被用於汽車、航空、印刷等工業產業上。此篇論文應用胺基磺酸鎳鍍液系統，所採用的電源形式為脈衝電流，其能提高鍍層磷含量並改善電流效率與內應力，並利用稍與圓環式(block-on-ring)的磨耗測試方法研究鎳磷合金腐蝕與磨耗的特性。測試的環境包括乾磨耗與浸在25 °C和50 °C的5%重量濃度鹽水腐蝕液中腐蝕磨耗，討論比較摩擦係數、磨耗率與表面粗糙度之間的關係。在邊界潤滑下，最初乾磨耗有著研磨磨耗與黏著磨耗的特性，最終研磨磨耗主導了磨耗形式，而加速腐蝕形成的腐蝕膜，不僅降低摩擦係數而且也改善磨耗率。

關鍵詞：鎳磷合金鍍層；內應力；腐蝕磨耗；邊界潤滑；腐蝕膜

## 目錄

封面內頁 簽名頁 授權書.....	iii	中文摘要.....	iv	英文摘要.....	v	誌謝.....	vi	目錄.....	vii	?目錄.....	xi	表目錄.....	xiv																																																																																																																		
第一章 緒論.....	1	1.1 前言.....	1	1.2 研究動機.....	2	2 第二章 文獻探討.....	3	2.1 電鍍製程相關理論.....	3	2.1.1 電鍍基本原理.....	3	2.1.2 合金電鍍之電解定律與電流效率.....	4	2.1.3 鎳電鍍液系統種類.....	6	2.1.4 脈衝參數對電鍍過程之影響.....	6	2.1.5 鍍層內應力.....	8	2.2 鎳磷合金技術.....	9	2.2.1 主導磨耗特性之因素.....	9	2.2.2 磨耗類型.....	10	2.2.3 磨耗機構.....	13	2.3 腐蝕破壞形式.....	15	2.3.1 均勻腐蝕.....	15	2.3.2 間隙腐蝕.....	16	2.3.3 穿孔腐蝕.....	18	2.3.4 伽凡尼腐蝕.....	19	2.3.5 去合金腐蝕.....	20	2.4 鎳磷合金鍍層的腐蝕磨耗.....	21	2.4.1 磨耗量測方法與磨耗行為.....	21	2.4.2 鍍層內應力、硬度及晶粒大小.....	22	2.4.3 腐蝕量測與腐蝕行為.....	23	第三章 實驗方法.....	25	3.1 實驗設備.....	26	3.1.1 試片製作設備.....	26	3.1.2 試片測試.....	29	3.2 試片製作.....	31	3.3 鍍前處理.....	32	3.4 鍍液組成與配置.....	34	3.5 微硬度試驗.....	34	3.6 鍍層內應力量測.....	35	3.7 磨耗性質試驗.....	38	3.7.1 磨耗性質試驗.....	38	3.7.2 磨耗腐蝕試驗.....	38	3.7.3 試片重量損失量之量測.....	39	3.7.4 摩擦係數的量測.....	39	3.8 表面粗糙度量測.....	39	3.8.1 中心線平均粗糙度.....	40	3.8.2 十點平均粗糙度.....	41	3.9 磨耗面與腐蝕磨耗面之觀察.....	42	第四章 實驗結果與討論.....	43	4.1 鍍層成份與性質.....	43	4.1.1 鍍層內應力.....	44	4.1.2 電流效率.....	45	4.1.3 硬度量測.....	46	4.2 乾磨耗試驗.....	47	4.2.1 乾磨耗表面形貌與磨耗殘留物成份分析.....	48	4.3 室溫腐蝕磨耗試驗.....	50	4.3.1 室溫腐蝕磨耗表面形貌.....	50	4.3.2 室溫腐蝕表面形貌.....	51	4.4 高溫腐蝕磨耗試驗.....	53	4.4.1 高溫腐蝕磨耗表面形貌.....	53	4.4.2 高溫腐蝕表面形貌.....	54	4.5 討論.....	56	4.5.1 磨擦係數和磨耗速率.....	56	4.5.2 腐蝕及磨耗之表面形貌.....	58	4.5.3 XPS的分析.....	60	4.5.4 XRD的分析.....	62	第五章 結論與未來展望.....	64	5.1 結論.....	64	5.2 未來展望.....	64	參考文獻.....	66

## 參考文獻

- [1].D. S. Lashmore and J. F. Weinroth, " Pulse Electrodeposition of Nickel-Phosphorus Metallic Glass Alloys, " Plating Surface Finishing, 69(72-76), 1982.
- [2].L. Wang, Y. Gao, T. Xu, Q. Xue, " Corrosion Resistance and Lubricated Sliding Wear Behaviour of Novel Ni – P Graded Alloys as an Alternative to Hard Cr Deposits, " Applied Surface Science 252 (7361 – 7372), 2006.
- [3].A. Bai, P. Y. Chuang, C. C. Hu, " The Corrosion Behavior of Ni-P Deposits with High Phosphorus Contents in Brine Media, " Materials Chemistry and Physics 82 (93-100), 2003.
- [4].許倍誠, " 電鍍鎳組織與機械性質之研究 ", 大葉大學機械工程研究所碩士論文, 2000年2月。

- [5].鄧伊浚, “電鍍鎳鈷與鎳鐵合金組織與機械性質之研究”, 大葉大學機械工程研究所碩士論文, 2003年6月。
- [6].陳黼澤, “鎳磷與鈷磷合金電鍍”, 國立台灣大學材料科學與工程學研究所碩士論文, 2005年7月。
- [7].蘇葵陽、張良謙, “實用電鍍理論與實際”, 復文書局, 1986年。
- [8].N. S. Qu, K. C. Chan and D. Zhu, “Surface Roughening in Pulse Current and Pulse Reverse Current Electroforming of Nickel,” *Surface and Coatings Technology*, Volume No.(220-224), 1997.
- [9].曾元宏, “脈衝電流應用於微電鍍最適化之研究”, 國立清華大學化學工程學系, 碩士論文, 2001年。
- [10].許仁哲, “內應力對無電鍍鎳銅磷析鍍於鋁基材上影響之研究”, 國立成功大學材料科學及工程學系, 博士論文, 2004年。
- [11].J. L. Carbajal, R. E. White, “Electrochemical Production and Corrosion Testing of Amorphous Ni-P,” *Journal of the Electrochemical Society*, 135 (2952-2957), 1988.
- [12].K. H. Hou, M. C. Jeng, M. D. Ger, “A study on the Wear Resistance Characteristics of Pulse Electroforming Ni – P Alloy Coatings as Plated,” *Wear*, 262 (833 – 844), 2007.
- [13].I. Apachitei, F.D. Tichelaar, J. Duszczyk, L. Katgerman, “The effect of heat treatment on the structure and abrasive wear resistance of autocatalytic NiP and NiP – SiC coatings,” *Surface and Coatings Technology* 149 (263 – 278), 2002.
- [14].A. P. Sannino, H.J. Rack, “Dry Sliding Wear of Discontinuously Reinforced Aluminum Composites :Review and Discussion,” *Wear*, 189, (1-19), 1995.
- [15].K. Z. Gahr, “Microstructure and Wear of Materials,” Elsevier Science Publishing Company Inc, 1987.
- [16].劉國雄, 林樹均, 李勝隆, 鄭晃忠, 葉均蔚編著, “工程材料科學”, 全華科技圖書, (834-837), 1995。
- [17].陳豐彥, 何信威, “燒結摩擦材料”, 粉末冶金手冊, 中華民國粉末冶金協會, (445-457), 1994。
- [18].莊東漢編著, “材料破損分析”, 五南圖書, (368-379), 2007。
- [19].柯賢文編著, “腐蝕及其防治”, 全華科技圖書, 1985。
- [20].鮮祺振編著, “金屬腐蝕特性討論” 徐氏基金會 1998/01/10。
- [21].D. A. Jones, “Principles and Prevention of Corrosion,” 2Ed, Prentice Hall International, Inc., (44-171),1997.
- [22].D. H. Jeong, U. Erb, K. T. Aust, G. Palumbo, “The Relationship Between Hardness and Abrasive Wear Resistance of Electrodeposited Nanocrystalline Ni-P Coatings,” *Scripta Materialia* 48 (1067-1072) 2003.
- [23].I. Apachiter, F. D. Tichelaar, J. Duszczyk, L. Katgerman, “The Effect of Heat Treatment on the Structure and Abrasive Wear Resistance of Autocatalytic NiP and NiP – SiC Coatings”, *Surface and Coatings Technology* 149 (2002) 263-278.
- [24].S. Alirezai, S. M. Monirvaghefi, M. Salehi, A. Saatchi, “Wear Behavior of Ni-P and Ni-P-Al<sub>2</sub>O<sub>3</sub> Electroless Coatings,” *Wear* 262 (978-985) 2007.
- [25].V. V. N. Reddy, B. Ramamoorthy, P. K. Nair, “A Study on the Wear Resistance of Electroless Ni-P/Diamond Composite Coatings,” *Wear* 239 (111-116) 2000.
- [26].B. Bozzini, C. Martini, P. L. Cavallotti, E. Lanzoni, “Relationships Among Crystallographic Structure, Mechanical Properties and Tribological Behaviour of Electroless Ni-P(9%)/B<sub>4</sub>C Films,” *Wear* 225 – 229 (806-813) 1999.
- [27].L. Wang, Y. Gao, T. Xu, Q. Xue, “Corrosion Resistance and Lubricated Sliding Wear Behaviour of Novel Ni – P Graded Alloys as an Alternative to Hard Cr Deposits,” *Applied Surface Science* 252 (7361 – 7372) 2006.
- [28].C. S. Lin, C. Y. Lee, F. J. Chen and W. C. Li, J. “Structural Evolution and Internal Stress of Nickel-Phosphorus Electrodeposits,” *Journal of the Electrochemical Society*, 152 (C370)2005.
- [29].K. H. Hou, M. C. Jeng, M. D. Ger, “A Study on the Wear Resistance Characteristics of Pulse Electroforming Ni – P Alloy Coatings as Plated,” *Wear*, 262 (833 – 844) 2007.
- [30].D. H. Jeong, U. Erb, K. T. Aust, G. Palumbo, “The Relationship Between Hardness and Abrasive Wear Resistance of Electrodeposited Nanocrystalline Ni-P Coatings,” *Scripta Materialia* 48 (1067-1072) 2003.
- [31].I. Apachiter, F. D. Tichelaar, J. Duszczyk, L. Katgerman, “The Effect of Heat Treatment on the Structure and Abrasive Wear Resistance of Autocatalytic NiP and NiP – SiC Coatings,” *Surface and Coatings Technology* 149 (263-278) 2002.
- [32].S. Alirezai, S. M. Monirvaghefi, M. Salehi, A. Saatchi, “Wear Behavior of Ni-P and Ni-P-Al<sub>2</sub>O<sub>3</sub> Electroless Coatings,” *Wear* 262 (978-985) 2007.
- [33].L. Wang, Y. Gao, T. Xu, Q. Xue, “Corrosion Resistance and Lubricated Sliding Wear Behaviour of Novel Ni – P Graded Alloys as an Alternative to Hard Cr Deposits,” *Applied Surface Science* 252 (7361 – 7372) 2006.
- [34].A. Bai, P. Y. Chuang, C. C. Hu, “The Corrosion Behavior of Ni-P Deposits with High Phosphorus Contents in Brine Media,” *Materials Chemistry and Physics* 82 (93-100) 2003.
- [35].B. Bozzini, P. L. Cavallotti, G. Parisi, “Corrosion and Erosion Corrosion of Electrodeposited Ni-P/ B<sub>4</sub>C Composites,” *British Corrosion Journal* 36 (49-55) 2001.
- [36].L. Benea, P. L. Bonora, A. Borello, S. Martelli, “Effect of SiC Size Dimensions on the Corrosion Wear Resistance of the Electrodeposited Composite Coating,” *Materials and Corrosion* 53 (23-29) 2002.
- [37].張仁威, “矽晶圓輪磨表面粗糙度預測模型之研究”, 大葉大學機械工程研究所碩士論文, 2007年6月。