



NASF SURFACE TECHNOLOGY WHITE PAPERS
80 (9), 50-56 (June 2016)

The 14th William Blum Lecture
Presented at the 60th AES Annual Convention in Minneapolis, Minnesota
June 18, 1973

Current Distribution on Microprofiles

Part 4

by

Otto Kardos

M&T Chemicals

Ferndale, Michigan

Recipient of the 1972 William Blum
AES Scientific Achievement Award



Contents (Part 4)

19. References
20. About the author

51
56



NASF SURFACE TECHNOLOGY WHITE PAPERS
80 (9), 50-56 (June 2016)

The 14th William Blum Lecture
Presented at the 60th AES Annual Convention in Minneapolis, Minnesota
June 18, 1973

Current Distribution on Microprofiles

Part 4

by

Otto Kardos

M&T Chemicals

Ferndale, Michigan

Recipient of the 1972 William Blum

AES Scientific Achievement Award

Reference List and Author Biography

Editor's Note: Originally published as *Plating*, 61 (2), 129-138 (1974), *Plating*, 61 (3), 229-237 (1974) and *Plating*, 61 (4), 316-325 (1974) this article is the last of four parts of a re-publication of the 14th William Blum Lecture, presented at the 60th AES Annual Convention in Cleveland, on June 18, 1973.

References

1. D.G. Foulke and O. Kardos, *Proc. Am. Electroplaters' Soc.*, **43**, 172 (1956).
2. O. Kardos, *ibid.*, 181.
3. S.A. Watson and J. Edwards, *Trans. Inst. Metal Finishing*, **34**, 167 (1957).
4. H. Leidheiser, *Z. Elektrochemie*, **59**, 756 (1955).
5. J.D. Thomas, *Proc. Am. Electroplaters' Soc.*, **43**, 60 (1956).
6. E.B. Leffler and H. Leidheiser, *Plating*, **44**, 388 (1957); AES Research Report, Serial No. 37.
7. O. Kardos and D.G. Foulke, "Electrodeposition on Small-Scale Profiles," in *Advances in Electrochemistry and Electrochemical Engineering, Vol. 2*, Ed. C. W. Tobias, Interscience, New York, 1962.
8. O. Kardos and D.G. Foulke, "Symposium on Electrodeposition and Metal Finishing," India Section of the Electrochem. Soc., Bangalore, 1957; p. 7.
9. E. Raub and K. Müller, *Fundamentals of Metal Deposition*, Elsevier Publishing Company, Amsterdam and New York, 1967.
10. O. Kardos, *Proc. Internat. Conf. (Basel), "Surface 66"*, Forster Verlag, Zurich; p. 62.
11. S.S. Kruglikov, "Surface Leveling in the Electrodeposition of Metals," in *Achievements of Science, Electrochemistry 1965*, Ed. S. S. Kruglikov (English translation for U.S. Dept. of Commerce).
- 11A. N.P. Gnusin and N.J. Kovarskii, "Roughness of Electrodeposited Surfaces," Academy of Science USSR, 1970, (In Russian).
12. A.R. Despic and K.I. Popov, "Transport-Controlled Deposition and Dissolution of Metals," in *Modern Aspects of Electrochemistry, No. 7*, Ed. B. E. Conway and J. O'M. Bockris, Plenum Press, New York, 1972.
13. W. Meyer, *Proc. Am. Electroplaters' Soc.*, **23**, 116, 135 (1935); **24**, 135 (1936).
14. G.E. Gardam, *J. Electrodepositors' Tech. Soc.*, **22**, 155 (1947).
15. C.E. Reinhard, *Proc. Am. Electroplaters' Soc.*, **37**, 171 (1950).
16. K.S. Willson and A.H. DuRose, *Plating*, **36**, 246 (1949).
17. A.H. DuRose, W.P. Karash and K.S. Willson, *Proc. Am. Electroplaters Soc.*, **37**, 193 (1950).
18. H.E. Haring and W. Blum, *Trans. Electrochem. Soc.*, **44**, 313 (1923).
19. C. Kasper, *ibid.*, (a) **77**, 353, 365 (1940); (b) **78**, 131, 147 (1940); (c) **82**, 153 (1942).
20. C. Wagner, *J. Electrochem. Soc.*, **98**, 116 (1951).
21. C. Wagner, "The Scope of Electrochemical Engineering," in *Advances in Electrochemistry and Electrochemical Engineering, Vol. 2*, Ed. C. W. Tobias, Interscience, New York, 1962.
22. J. Kronsbein, *Plating*, **37**, 851 (1950); **39**, 165 (1952); **40**, 898 (1953).
23. R.H. Rousselot, *Metal Finishing*, **57**, 56 (Oct. 1959).

NASF SURFACE TECHNOLOGY WHITE PAPERS 80 (9), 50-56 (June 2016)

24. H.L. Pinkerton, "Current and Metal Distribution," in *Electroplating Engineering Handbook*, Ed. A. K. Graham, 3rd Ed., Van Nostrand Reinhold Co., New York, 1971.
25. A.T. Yagramyan and Z.A. Soloveva, *Technology of Electrodeposition*, Robert Draper Ltd., Teddington, 1961.
26. E. Weber, *Electromagnetic Fields*, Vol. I, Wiley, New York, 1950.
27. E. Weber, *Swiss Bull. Electrical Eng.*, **51** (20), 1011 (Oct. 1960).
- 27A. J.A. Klingert, S. Lynn and C.W. Tobias, *Electrochim. Acta*, **9**, 297 (1964).
28. G.F. Kinney and J.V. Festa, *Plating*, **41**, 380 (1954) or *Proc. Am. Electroplaters' Soc.*, **41**, 66 (1954).
- 28A. J.J. Christie and J. Thomas, *Plating*, **52**, 855 (1965).
29. R.H. Rousselot, *J. Rech. Centre Nat. Rech. Sci., Lab. Bellevue, Paris, (S. et O.)*, No. 52 (Sept. 1960).
- 29A. K.C. Clements-Jewery, *Electroplating Metal Finishing*, **26**, (4) 24 (1973).
30. J. O'M Bockris and A.K.N. Reddy, *Modern Electrochemistry*, 2 volumes, Plenum Press, New York, 1970.
- 30A. J. O'M Bockris, *J. Chem. Educ.*, **48**, 353 (1971).
31. K.J. Vetter, *Electrochemical Kinetics*, Academic Press, New York, 1967.
32. D.B. Matthews and J. O'M Bockris, "The Mechanism of Charge Transfer from Metal Electrodes to Ions in Solutions," in *Modern Aspects of Electrochemistry*, No. 6, Ed. Bockris and Conway, Plenum Press, New York, 1971.
33. J. O'M. Bockris and D. Drazic, *Electrochemical Science*, Taylor & Francis Ltd., London, 1972.
34. E.H. Lyons, *Introduction to Electrochemistry*, D.C. Heath & Co., Boston, 1967.
35. J.M. West, *Electrodeposition and Corrosion Processes, 2nd Ed.*, Van Nostrand Reinhold Company, New York, 1970.
- 35A. T.P. Hoar, *Plating*, **61**, 35 (1974).
36. R. de Levie, "Electrochemical Responses of Porous and Rough Electrodes," in *Advances in Electrochemistry and Electrochemical Engineering, Vol. 6*, Ed. P. Delahay, Interscience, New York, 1967.
37. R. de Levie, *Electrochim. Acta*, **10**, 113 (1965).
38. E. Mattson and J. O'M. Bockris, *Trans. Faraday Soc.*, **55**, 1586 (1959).
39. J. O'M. Bockris and M. Enyo, *ibid.*, **58**, 1187 (1962).
40. J. O'M. Bockris and H. Kita, *J. Electrochem. Soc.*, **109**, 928 (1962).
41. A.H. DuRose, *Trans. Inst. Metal Finishing*, **38**, 27 (1961).
42. R. Wiart, *Oberfläche-Surface*, **9**, 213, 241, 275 (1968).
43. W.A. Wesley and E.J. Roehl, *Trans. Electrochem. Soc.*, **86**, 419 (1944).
44. L.B. Garmon and H. Leidheiser, *Proc. Am. Electroplaters' Soc.*, **46**, 50 (1959).
- 44A. W. Blum and G.B. Hogaboom, *Principles of Electroplating and Electroforming, 3rd Ed.*, McGraw-Hill, New York, 1949; p. 434.
45. E. Raub, *Plating*, **45**, 486 (1958).
- 45A. K. Müller and E. Raub, *Metalloberfläche*, **15**, 357 (1961); E. Raub and K. Müller, *ibid.*, **17**, 97 (1963).
46. D.G. Foulke, *Metal Finishing*, **54**, 52 (Oct. 1956).
47. A. Brenner, *Proc. Am. Electroplaters' Soc.*, **28**, 95 (1940); *ibid.*, **29**, 28 (1941).
48. N. Ibl, *Proc. Internat. Conf. (Basel) "Surface 66"*, Forster Verlag, Zurich, p. 48.
49. N. Ibl and R. Müller, *Z. Elektrochem.*, **59**, 671 (1955).
50. N. Ibl, *Galvanotechnik ir Oberflächenschutz*, **4**, 265 (1963).
51. A. Tvarusko and L.S. Watkins, *Electrochim. Acta*, **14**, 1109 (1969).
52. R.N. Adams, *Electrochemistry of Solid Electrodes*, Marcel Dekker, New York, 1969.
53. W.C. Elmore, *J. Appl. Phys.*, **10**, 724 (1939); *ibid.*, **11**, 797 (1940).
54. J. Edwards, *J. Electrodepositors' Tech. Soc.*, **28**, 133 (1951-1952); *J. Electrochem. Soc.*, **100**, 189C (1953); *ibid.*, 223C.
55. C. Wagner, *J. Electrochem. Soc.*, **101**, 225 (1954).
56. N. Ibl, "The Formation of Powdered Metal Deposits," in *Advances in Electrochemistry and Electrochemical Engineering, Vol. 2*, Ed. C. W. Tobias, Interscience, New York, 1962.
57. V.G. Levich, *Chemical Hydrodynamics*, Prentice-Hall, Englewood Cliffs, New Jersey, 1962.
58. L.L. Bircumshaw and A.C. Riddiford, *Quart. Rev. (London)*, **6** (2), 157 (1952).
59. J. Newman, "Transport Processes in Electrolytic Solutions," in *Advances in Electrochemistry and Electrochemical Engineering, Vol. 5*, Ed. C.W. Tobias, Interscience, New York, 1967.
- 59A. A.R. Arvia and S.L. Marchiano, "Transport Phenomena in Electrochemical Kinetics," in *Modern Aspects of Electrochemistry, No. 6*, Ed. J. O'M. Bockris and B. E. Conway, Plenum Press, New York, 1971.
60. J. Edwards, *Trans. Inst. Metal Finishing*, **39**, 33 (1962).

NASF SURFACE TECHNOLOGY WHITE PAPERS
80 (9), 50-56 (June 2016)

61. *Ibid.*, **39**, 45 (1962).
62. *Ibid.*, **39**, 52 (1962).
63. *Ibid.*, **41**, 140 (1964).
64. *Ibid.*, **41**, 169 (1964), or **42**, 22 (1964).
65. J. Edwards and M.J. Levett, *ibid.*, **41**, 147 (1964).
66. *Ibid.*, **41**, 157 (1964).
67. *Ibid.*, **44**, 27 (1966).
68. *Ibid.*, **45**, 12 (1967).
69. *Ibid.*, **47**, 7 (1969).
70. Yu.K. Vyagis, A.I. Bodnevas and Yu.Yu. Matulis, *Protection of Metals (Zashchita Metallov)*, **1** (4), 318 (July-Aug. 1965); **1** (5), 468 (Sept.-Oct. 1965); **2** (2), 168 (March-April 1966); **2** (4), 388 (July-Aug. 1966), Consultants Bureau, New York.
71. E. Raub, A. Knodler, A. Disam and H. Kawase, *Proc. Internat. Conf. (Hannover)*, "Interfinish 68," Eugen G. Leuze Verlag, D-7968, Saulgau, Wurtt., p. 52; *Metalloberfläche*, **23**, 293 (1969).
72. E. Raub, N. Baba, A. Knodler and M. Stalzer, *Trans. Inst. Metal Finishing*, **42**, 108 (1964).
73. G.T. Rogers and K.J. Taylor, *Electrochim. Acta*, **8**, 887 (1963).
74. G.T. Rogers and K.J. Taylor, *Trans. Inst. Metal Finishing*, **43**, 75 (1965).
75. C.C. Roth and H. Leidheiser, *J. Electrochem. Soc.*, **100**, 553 (1953).
76. E. Raub and M. Wittum, *Z. Elektrochem.*, **46**, 71 (1940); *Metal Ind. (London)*, **38**, 206, 315, 429 (1940).
77. J. Edwards in discussion of reference 99, p. 136.
78. A. DuRose, *Proc. Internat. Conf. (Hannover)*, "Interfinish 68," Eugen G. Leuze Verlag, D-7968 Saulgau, Wurtt., p. 54.
79. American Standard ASA B46.1-1962, Surface Texture, Am. Soc. of Mechanical Engineers, New York.
80. H.L. Kellner, *Proc. Am. Electroplaters' Soc.*, **37**, 105 (1950).
81. A.G. Strang and F. Ogburn, *ibid.*, **37**, 125 (1950).
82. S.S. Kruglikov and T.A. Smirnova, *Proc. 8th Internat. Metal Finishing Congress, (Basel) "Interfinish 1972,"* Forster Verlag, Zurich, 1973; p. 105; S.S. Kruglikov, N.T. Kudryavtsev, G.I. Medvedev and T.M. Izmailova, *Protection of Metals (Zashchita Metallov)*, **8** (6), 668 (Nov.-Dec. 1972), Consultants Bureau, New York, and *Galvanotechnik*, **63**, 955 (1972).
- 82A. E. Bertorelle, I.R. Bellobono and C. Bordonali, *Trans. Inst. Metal Finishing*, **35**, 231 (1957-58).
83. C. Wagner, *Electrochim. Acta*, **12**, 131 (1967).
84. L.B. Garmon and H. Leidheiser, *Plating*, **48**, 1003 (1961).
85. C. Wagner, L.B. Garmon and H. Leidheiser, AES Research Report No. 50 (1962).
86. C. Wagner, *Plating*, **48**, 997 (1961).
87. B.E. Conway and J. O'M. Bockris, AES Research Report, Serial No. 41; *Plating*, **46**, 371 (1959).
88. J. O'M. Bockris and G. A. Razumney, *Fundamental Aspects of Electrocrystallization*, New York, Plenum Press, 1967.
89. J. O'M. Bockris and A. Damjanovic, "The Mechanism of the Electrodeposition of Metals" in *Modern Aspects of Electrochemistry, No. 3*, Ed. J. O'M. Bockris and B.E. Conway, Washington, Butterworths, 1964.
90. A. Damjanovic, AES Research Report Serial No. 55 (1966); *Plating*, **52**, 1017 (1965).
91. A. A. Voronko, *Zh. Priklad. Khim.*, **35**, 2802 (1962).
92. S.S. Kruglikov, N.T. Kudryavtsev and R.P. Sobolev, *Tr. Mosk. Khim.-Technol. Inst. Mendeleev*, **32**, 259 (1961).
93. E. Raub and M. Stalzer, *Metalloberfläche*, **17**, 134 (1963).
94. V.G. Levich, *Acta Physicochim. USSR*, **17**, 257 (1942).
95. A.C. Riddiford, "The Rotating Disk System" in *Advances in Electrochemistry and Electrochemical Engineering, Vol. 4*, Ed. P. Delahay, New York, Interscience, 1966.
96. D.P. Gregory and A.C. Riddiford, *J. Chem. Soc.*, 3756 (1956).
97. J.D. Newson and A.C. Riddiford, *J. Electrochem. Soc.*, **108**, 695 (1961).
98. S.S. Kruglikov, G.F. Vorobeve, N.T. Kudryavtsev, M.M. Yarlikov, A.Ya. Antonov and R.G. Erenburg, in *Theory and Practice of Bright Plating, Proc. All-Union Conference in Vilnyus (Dec. 1962)*, p. 20 (English translation for U.S. Dept. of Commerce).
99. S.S. Kruglikov, N.T. Kudryavtsev, A.Ya. Antonov and A.V. Dribinski, *Trans. Inst. Metal Finishing*, **42**, 129 (1964).
100. S.S. Kruglikov, N.T. Kudryavtsev and R.P. Sobolev, *Electrochim. Acta*, **12**, 1263 (1967).
101. S.S. Kruglikov, N.T. Kudryavtsev, G.F. Vorobiova and A.Ya. Antonov, *ibid.*, **10**, 253 (1965).
102. S.S. Kruglikov, N.T. Kudryavtsev and E.V. Semina, *Proc. Internat. Conf. (Hannover) "Interfinish 68,"* E.G. Leuze Verlag, D-7968 Saulgau, Wurtt., p. 66.

NASF SURFACE TECHNOLOGY WHITE PAPERS
80 (9), 50-56 (June 2016)

103. S.S. Kruglikov, N.T. Kudryavtsev and E.V. Semina, "3rd Internat. Congress on Corrosion, Moscow 1966," Vol. 3, pp. 323-332.
104. S.S. Kruglikov, E.V. Semina and N.T. Kudryavtsev, *Protection of Metals (Zashchita Metallov)*, **3** (1), 69 (1967), Consultants Bureau, New York.
105. G.T. Rogers and K.J. Taylor, *Electrochim. Acta*, **11**, 1685 (1966).
106. G.T. Rogers and K.J. Taylor, *ibid.*, **13**, 109 (1968).
107. J. Schulz-Harder, Doctoral Thesis, Technische Universitat, Berlin (1971), D 83.
108. Yu. K. Vyagis, A. V. Skuchene and A. I. Bodnevas in *Electrodeposition of Metals, Proc. 10th Lithuanian Conference of Electrochemists* (1968) (English translation for U.S. Dept. of Commerce), p. 8.
109. Yu.Yu. Matulis, *Proc. 8th Internat. Metal Finishing Congress (Base)*, "Interfinish 1972," Forster Verlag, Zurich, 1973; p. 110.
110. S.S. Kruglikov and V.A. Volkov, *Soviet Electrochemistry (Elektrokhimiya)*, **6**, 1690 (Nov. 1970), Consultants Bureau, New York.
111. S.A. Watson, *Trans. Inst. Metal Finishing*, **37**, 144 (1960).
112. E.B. Saubestre, *Plating*, **45**, 1219 (1958).
113. H. Brown, *ibid.*, **55**, 1047 (1968).
114. H. Brown, *Trans. Inst. Metal Finishing*, **47**, 63 (1969).
115. H. Brown, *Proc. 8th Internat. Metal Finishing Congress (Base)* "Interfinish 1972," Forster Verlag, Zurich, 1973; p. 114.
116. S. E. Beacom and B.J. Riley, *J. Electrochem. Soc.*, **106**, 309 (1959).
117. S. E. Beacom and B. J. Riley, *ibid.*, **107**, 785 (1960).
118. S. E. Beacom and B. J. Riley, *ibid.*, **108**, 758 (1961).
119. S. E. Beacom and B.J. Riley, *Record Chem. Progr.*, **24**, No. 2, 75 (1963).
120. W. R. Doty and B. J. Riley, *J. Electrochem. Soc.*, **114**, 50 (1967).
121. Ph. Javet, N. Ibl and H. E. Hintermann, *Galvanotechnik Oberflächenschutz*, **8**, 231 (1967).
122. Ph. Javet, "Contribution à la connaissance de la cinétique du transport et de l'action de la thiourée lors de la deposition électrolytique," Thesis, Microtecnic Scriptar S. A., 1001 Lausanne (1966).
123. N. Ibl, *Traitements de Surface*, 20 (March 1967).
124. K. Balakrishnan and H. Fischer, *Trans. Inst. Metal Finishing*, **43**, 192 (1965).
125. Ph. Javet, N. Ibl and H.E. Hintermann, *Electrochim. Acta*, **12**, 781 (1967).
126. S.S. Kruglikov, N.T. Kudryavtsev and U.I. Sinyakov, *Trans. Inst. Metal Finishing*, **44**, 152 (1966).
127. T. Mine, R. Tominaga and T. Seiyama, *Denki Kagaku*, **35** (7), 472 (1967).
- 127A. E. Raub and T. Schifner, *Metalloberfläche*, **25**, 114 (1971).
128. H.A. Laitinen and B. Mosier, *J. Am. Chem. Soc.*, **80**, 2363 (1958).
129. A.N. Frumkin and B.B. Damaskin, "Adsorption of Organic Compounds at Electrodes" in *Modern Aspects of Electrochemistry, No. 3*, Ed. J. O'M. Bockris and B. E. Conway, Butterworths, Washington, 1964.
130. B.B. Damaskin, O.A. Petrii and V.V. Batrakov, *Adsorption of Organic Compounds on Electrodes*, Plenum Press, New York, 1971.
131. O. Volk and H. Fischer, *Electrochim. Acta*, **4**, 251 (1961).
132. S.S. Kruglikov, N.T. Kudryavtsev, R.P. Sobolev and A.Ya. Antonov, *Plating*, **53**, 78 (1966).
133. A.R. Despic and K.I. Popov, *J. Appl. Electrochem.*, **1**, 275 (1971); K.I. Popov, B.J. Lazarevic and M. Kostic, *ibid.*, **3**, 161 (1973).
- 133A. A.R. Despic, *Proc. 8th Internat. Metal Finishing Congress (Base)* "Interfinish 1972," Forster Verlag, Zurich, 1973; p. 89.
134. M. Braun and N. Ibl, *Oberfläche-Surface*, **14**, 49 (1973); *Proc. Internat. Metal Finishing Congress (Base)* "Interfinish 72," Forster Verlag, Zurich, 1973; p. 142.
135. M.Sh. Gladshstein and L.I. Kadaner, *Issled. Elektro-osazhden. Rastvoren. Metal* (1971), Ed. A.N. Frumkin, Nauka, Moscow, pp. 11-17.
136. *Chem. Abstr.*, **76**, 30048h (1972) and Kadaner in Discussion of ref. 137.
137. Yu.Yu. Matulis and B.M. Zilieniene, *Proc. 3rd Internat. Congress on Corrosion, Moscow 1966*, **3**, 316 (In English) Swets-Zeitlinger, Amsterdam.
138. K. Sundarayan, S.R. Rajagopalan and A.K.N. Reddy, *Electrochim. Acta*, **8**, 831 (1963).
139. R. Weil and R.A. Paquin, *J. Electrochem. Soc.*, **107**, 87 (1960).
140. I. Epelboin, M. Froment and G. Maurin, *Plating*, **56**, 1356 (1969).

NASF SURFACE TECHNOLOGY WHITE PAPERS
80 (9), 50-56 (June 2016)

141. A.T. Vagramyan and N.K. Baraboshkina, *ibid.*, **54**, 930 (1967).
142. R. Weil and H.C. Cook, *J. Electrochem. Soc.*, **109**, 295 (1962).
143. R. Weil and W.N. Jacobus, *Plating*, **53**, 102 (1966).
144. R. Weil and H.K. Tsourmas, *ibid.*, **49**, 624 (1962).
145. R. Weil, W.N. Jacobus and S.J. DeMay, *J. Electrochem. Soc.*, **111**, 1046 (1964).
146. O. Kardos, discussion of ref. 141 in *Plating*, **55**, 90 (1968).
147. G.G. Storey and S.C. Barnes, *Trans. Inst. Metal Finishing*, **37**, 11 (1960).
148. A. Damjanovic, T.H.V. Setty and J. O'M. Bockris, *J. Electrochem. Soc.*, **113**, 429 (1966).
149. A. Damjanovic, M. Paunovic and J. O'M. Bockris, *J. Electroanal. Chem.*, **9**, 93 (1965); *Electrochim. Acta*, **10**, 111 (1965).
150. M. Fleischmann and H.R. Thirsk, "Metal Deposition and Electrocrystallization" in *Advances in Electrochemistry and Electrochemical Engineering, Vol. 3*, Ed. P. Delahay, Interscience, New York, 1963.
151. H.J. Pick, G.G. Storey and T.B. Vaughan, *Electrochim. Acta*, **2**, 165, 179 (1960).
152. H. Fischer, *Angew. Chemie, Internat. Edit.*, **8** (2), 108 (1969).
153. H. Seiter, H. Fischer and L. Albert, *Electrochim. Acta*, **2**, 97 (1966).
154. H. Fischer, *Electrochim. Acta*, **2**, 50 (1966); *Plating*, **56**, 1229 (1969); *Elektrolytische Abscheidung und Elektrokristallisation von Metallen*, Springer Verlag, Berlin, 1954.
155. N. Ibl and K. Schadegg, *J. Electrochem. Soc.*, **114**, 54 (1967); N. Ibl in discussion of this paper, *ibid.*, 1267.
156. N. Ibl, Ph. Javet and F. Stahel, *Electrochim. Acta*, **17**, 733 (1972).
157. J.L. Barton and J. O'M. Bockris, *Proc. Royal Soc., London*, **A 268**, 485 (1962).
158. D.R. Hamilton, *Electrochim. Acta*, **8**, 731 (1963).
159. A.R. Despic, J. Diggle and J. O'M. Bockris, *J. Electrochem. Soc.*, **115**, 507 (1968); *ibid.*, **116**, 1503 (1969).
160. H.Y. Cheh, *ibid.*, **117**, 609 (1970).
161. T.P. Hoar, *Trans. Inst. Metal Finishing*, **29**, 302 (1953).
162. D.R. Turner and G.R. Johnson, *J. Electrochem. Soc.*, **109**, 798, 918 (1962).
163. H. Fischer, "Modes of Inhibiting Electrode Processes," *Werkstoffe Korrosion*, **23**, 445 (June 1972) (In English); *Electrodeposition Surface Treatment*, **1** (3), 239; **1**, (4), 319 (1972-73) Elsevier Sequoia S.A., Lausanne.
164. I. Epelboin, M. Froment and R. Wart, *C. fl. Acad. Sciences, Paris*, **260**, 3379 (1965).
165. R.W. Couch and R.G. Bikales, *Proc. Am. Electroplaters' Soc.*, **48**, 176 (1961).
166. J. W. Dini, *Plating*, **51**, 119 (1964).
167. B. F. Rothschild, *ibid.*, **53**, 437 (1966).
168. M. W. Jawitz in *Proc. Second Plating in the Electronics Industry Symposium*, Am. Electroplaters' Soc., (Feb. 1969), p. 5; *Metal Finishing*, **71**, 31 (July 1973).
- 168A. E.B. Saubestre and R.P. Khera in *Proc. Third Plating in the Electronics Industry Symposium*, Am. Electroplaters' Soc., (Feb. 1971), p. 230.
169. L.J. Quintana, *Proc. Am. Electroplaters' Soc.*, **51**, 170 (1964).
- 169A. H.L. Pinkerton and J.W. Smith, *Plating*, **59**, 672 (1972).
170. I.G. Gurevich and V.S. Bagotskii, *Electrochim. Acta*, **9**, 1151 (1964).
171. J.G. Sohm, *ibid.*, **7**, 629 (1962).
172. T.P. Hoar and J.A.S. Mowat, *Nature*, **165**, 64 (1950).
173. A. Hickling and H.P. Rothbaum, *Trans. Inst. Metal Finishing*, **34**, 53 (1957).
174. H.H. Heiling, *Metall*, **9** (17/18), 764 (1958).
175. T.P. Hoar, "The Anodic Behaviour of Metals" in *Modern Aspects of Electrochemistry, No. 2*, Ed., J. O'M. Bockris, Butterworths, Washington, 1959.
176. T.P. Hoar and G.P. Rothwell, *Electrochim. Acta*, **9**, 135 (1964).
177. N.Ya. Kovarskii and N.P. Gnusin, *Protection of Metals (Zashchita Metallov)*, **2**, 190 (March-April 1966), Consultants Bureau, New York.
178. N. Ibl and M. Braun, *Chemie-Ing. Technik*, **45** (4), 182 (1973).
179. T. Zak, *Trans. Inst. Metal Finishing*, **49**, 220 (1971).
180. K. Kojima and C.W. Tobias, *J. Electrochem. Soc.*, **120**, 1026 (1973).

NASF SURFACE TECHNOLOGY WHITE PAPERS 80 (9), 50-56 (June 2016)

About the author

This piece was written at the time Dr. Kardos was announced as the recipient of the 1972 Scientific Achievement Award:



The AES Scientific Achievement Award Selection Committee has chosen **Dr. Otto Kardos** to be the 1972 recipient of the award. The selection of Dr. Kardos was announced by chairman of the committee, Arthur H. DuRose, at the Opening Session of the 59th AES Annual Technical Conference in Cleveland on June 19, 1972.

Dr. Kardos retired from M&T Chemicals Inc., a wholly owned subsidiary of American Can Company, after 28 years in research on electroplating processes. He was a pioneer in developing modern bright plating processes and is the inventor of basic patents in this field. His contribution to modern theories of leveling in bright smooth electrodeposits is recognized internationally.

Dr. Kardos was born in 1907 in Vienna, Austria, where he received his primary and secondary education. In 1932, he obtained his Ph.D. degree in chemistry from the University of Vienna. He wrote his thesis on the kinetics of catalytic reactions involving peroxides and inorganic iodine compounds under Professor Emil Abel. His first job was as a chemist in the electroplating supply firm of "Galvapol" in Vienna. This introduction into electrodeposition led to his life work and interest in this field.

After the political upheaval in Austria in 1938, he left his native country and lived in France until 1942. While there he worked as an electroplating consultant, specializing in anodizing, coloring and electroplating on aluminum.

In 1942 he came with his wife and small daughter to New York. He worked briefly as an analytical chemist in an electroplating job shop, and then as a research electrochemist at a slide-fastener manufacturer, Conmar Products in Newark, New Jersey. In 1944 he joined the Hanson-Van Winkle-Munning Company at Matawan, New Jersey, which later became a part of M&T Chemicals, as a research electrochemist, and through the years was promoted to senior research associate. After the merger with M&T Chemicals Inc., he transferred in 1965 to the company's Detroit research laboratory.

Dr. Kardos specialized in the development of bright plating processes for nickel, copper, silver, zinc, cadmium and cobalt and is the inventor or co-inventor of 30 U. S. patents along with corresponding foreign patents. Among these is a basic pioneering patent on which most modern bright leveling nickel plating processes are based. He developed - in cooperation with Dr. D.G. Foulke - a now generally accepted theory on the mechanism of leveling and microthrowing power during electrodeposition on small-scale profiles. For papers published in 1957 he received the American Electroplaters' Society's highest award for the best technical paper published in the Society's publications. Dr. Kardos reviewed the theories for leveling and microthrowing power in the field of electroplating in a chapter in *Advances in Electrochemistry and Electrochemical Engineering, Vol. 2* edited by Professor Charles Tobias of the University of California and published in 1962. He was invited to update his theories on the mechanism of leveling in a paper which he presented at the International Metal Finishing Conference in Basel, Switzerland, in November 1966.

He was a member of various Research Project Committees of the American Electroplaters' Society for many years. He is a member of the American Electroplaters' Society, Electrochemical Society, the American Chemical Society and the American Association for the Advancement of Science.

In his retirement he plans to continue as a consultant for M&T Chemicals. Besides consulting in electrochemistry, Dr. Kardos plans to enjoy reading in scientific fields, listening to classical music, playing the piano, gardening, walking, and - last but not least - babysitting for his grandson.