

When evaluating the importance of the selected groups of steel thermochemical technologies presented in the chapter, their broad scale of contemporary applications in the industry should be emphasised, and in many cases the fact that they cannot be replaced with reasonable alternatives having similar costs. Hence, they will certainly still be important in the nearest 20 years amongst other technologies of engineer materials surface engineering, which justifies their position in *The Critical Technologies Book*.

## References

1. A.D. Dobrzańska-Danikiewicz, E-foresight of materials surface engineering, *Archives of Materials Science Engineering* 44/1 (2010) 43-50.
2. A.D. Dobrzańska-Danikiewicz, Foresight methods for technology validation, roadmapping and development in the surface engineering area, *Archives of Materials Science Engineering* 44/2 (2010) 69-86.
3. A.D. Dobrzańska-Danikiewicz, Main assumptions of the foresight of surface properties formation leading technologies of engineering materials and biomaterials, *Journal of Achievements in Materials and Manufacturing Engineering* 34/2 (2009) 165-171.
4. L.A. Dobrzański, E. Hajduczek, J. Marciniak, R. Nowosielski, *Physical metallurgy and heat treatment of tool materials*, WNT, Warsaw, 1990 (in Polish).
5. L.A. Dobrzański, *Engineering materials and materials design. Fundamentals of materials science and physical metallurgy*, WNT, Warsaw, 2006 (in Polish).
6. T. Burakowski, T. Wierchoń, *Surface Engineering of Metals*, WNT, Warsaw, 1995 (in Polish).
7. P. Kula, *Surface Layer Engineering*, Monographs No. 983, Publishing House of Technical University of Lodz, Lodz, 2000 (in Polish).
8. F.A.P. Fernandes, S.C. Heck, R.G. Pereira, A. Lombardi-Neto, G.E. Totten, L.C. Casteletti, Wear of plasma nitrided and nitrocarburised AISI 316L austenitic stainless steel, *Journal of Achievements in Materials and Manufacturing Engineering* 40/2 (2010) 175-179.
9. Z. Gawroński, B. Kruszyński, P. Kula, Synergistic effects of thermo-chemical treatment and super abrasive grinding in gears' manufacturing, *Journal of Materials Processing Technology* 159/2 (2005) 249-256.
10. P. Kula, R. Pietrasik, K. Dybowski, Vacuum carburizing – process optimization, *Journal of Materials Processing Technology* 164-165 (2005) 876-881.
11. A. Sugianto, M. Narazaki, M. Kogawara, A. Shirayori, S.-Y. Kim, S. Kubota, Numerical simulation and experimental verification of carburizing-quenching process of SCr420H steel helical gear, *Journal of Materials Processing Technology* 209/7 (2009) 3597-3609.

12. R.L. Liu, M.F. Yan, D.L. Wu, Microstructure and mechanical properties of 17-4PH steel plasma nitrocarburized with and without rare earths addition, *Journal of Materials Processing Technology* 210/5 (2010) 784-790.
13. G.-J. Li, J. Wang, Q. Peng, C. Li, Y. Wang, B.-L. Shen, Influence of salt bath nitrocarburizing and post-oxidation process on surface microstructure evolution of 17-4PH stainless steel, *Journal of Materials Processing Technology* 207/1-3 (2008) 187-192.
14. J. Ratajski, T. Suszko, Modelling of the nitriding process, *Journal of Materials Processing Technology* 195/1-3 (2008) 212-217.
15. K. Genel, Estimation method for the fatigue limit of case hardened steels, *Surface & Coatings Technology* 194 (2005) 91-95.
16. D.-W. Kim, B.-S. Lim, Plasma and Vacuum Carburizing Processes and Mechanical Properties of SCM 415 Steel, *KSME International Journal* 13/8 (1999) 634-641.
17. S.-K. Lyu, K. Inoue, G. Deng, M. Kato, Effect of Surface Treatments on the Strength of Carburized Gears – An Application of Fracture Mechanics, *KSME International Journal* 12/2 (1998) 206-214.
18. I.N. Roslyakov, V.I. Kolmykov, Influence of Nitrocementation on the Increase in Fatigue Strength and Wear Resistance of Galvanic Iron Coatings, *Russian Engineering Research* 29/9 (2009) 903-904.
19. M. Fujii, M. Seki, A. Yoshida, Surface durability of WC/C-coated case-hardened steel gear, *Journal of Mechanical Science and Technology* 24 (2010) 103-106.
20. P. Kula, J. Olejnik, J. Kowalewski, New vacuum carburizing technology, *Heat Treating Progress* 1 (2001) 57-60.
21. M. Szota, J. Jasiński, Modelling of carburising parameters, *Materials Engineering* 1 (2010) 614-618 (in Polish).
22. J. Walkowicz, J. Smolik, C. Bertrand, A. Ioncea, Thermochemical treatment and operating life of hot forging dies, *Materials Engineering* 5 (2005) 214-218 (in Polish).
23. P. Kochmański, J. Nowacki, Initial growth phase of gas-nitrided layer on 17-4PH precipitation hardening stainless steel, *Materials Engineering* 5 (2005) 314-318 (in Polish).
24. K. Maruśić, H. Otmačić, D. Landek, F. Cajner, Modification of carbon steel surface by the Tenifer® process of nitrocarburizing and post-oxidation, *Surface & Coatings Technology* 201 (2006) 3415-3421.
25. Z. Gawroński, A. Malasiński, J. Sawicki, A selection of the protective atmosphere eliminating the inter-operational copper plating step in the processing of gear wheels, *Archives of Materials Science and Engineering* 44/1 (2010) 51-57.
26. G.H. Farrahi, H. Ghadbeigi, An investigation into the effect of various surface treatments on fatigue life of a tool steel, *Journal of Materials Processing Technology* 174/1-3 (2006) 318-324.
27. R.L.O. Basso, R.J. Candal, C.A. Figueroa, D. Wisnivesky, F. Alvarez, Influence of microstructure on the corrosion behavior of nitrocarburized AISI H13 tool steel obtained by pulsed DC plasma, *Surface & Coatings Technology* 203 /10-11 (2009) 1293-1297.

28. D.-C. Wen, Erosion and wear behavior of nitrocarburized DC53 tool steel, *Wear* 268/3-4 (2010) 629-636.
29. W. Gräfen, B. Edenhofer, New developments in thermo-chemical diffusion processes, *Surface & Coatings Technology* 200/5-6 (2005) 1830-1836.
30. T. Babul, Z. Obuchowicz, W. Grzelecki, Nitro-Oxidation of Tools Manufactured from High-Speed Steel, *Materials and Manufacturing Processes* 24/7-8 (2009) 842-846.
31. K.-T. Youn, Y.-M. Rhyim, J.-H. Lee, C.-G. Lee, Y.-C. Jung, An Evaluation of Thermal Fatigue Cracking and Chemical Reaction in Die Casting Mould, *Key Engineering Materials* 345-346 (2007) 701-704.
32. J. Smolik, J. Walkowicz, J. Tacikowski, Influence of the structure of the composite: 'nitrided layer/PVD coating' on the durability of tools for hot working, *Surface & Coatings Technology* 125/1-3 (2000) 134-140.
33. J. Smolik, M. Gulde, J. Walkowicz, J. Suchanek, Influence of the structure of the composite: 'nitrided layer/PVD coating' on the durability of forging dies made of steel DIN-1.2367, *Surface & Coatings Technology* 180-181 (2004) 506-511.
34. J. Adamczyk, M. Przybył, Effect of nitriding on structure and properties of high-speed steels, *Works by the Institute for Ferrous Metallurgy* 33/34 (1978) 109-114 (in Polish).
35. J. Adamczyk, M. Przybył, Effect of nitriding conditions on mechanical properties of selected tool steel grades, *Proceedings of the Conference on Carbides–nitrides–borides*, Poznań, 1981, 260-272 (in Polish).
36. J. Adamczyk, M. Przybył, E. Hajduczek, Structure of nitrides layers on selected tool steels, *Proceedings of the 6<sup>th</sup> Conference on Electron Microscopy of Solids*, Kraków – Krynica, 1981, 266-270 (in Polish).
37. J. Adamczyk, E. Hajduczek, Effect of surface diffusion layers on thermal fatigue of hot work tool X40CrMoV5-1 steel, *Metal Science and Heat Treatment* 66 (1983) 9-14 (in Polish).
38. J. Adamczyk, E. Hajduczek, Phase composition of surface layer of diffusion borided X40CrMoV5-1 steel, *Proceedings of the 3<sup>rd</sup> International Conference "Carbides, nitrides, borides"*, Poznań – Kołobrzeg, 1984, 272-278 (in Polish).
39. J. Adamczyk, E. Hajduczek, L.A. Dobrzański, M. Czech, H. Słupik, Cutting ability tests for thermochemically treated HS6-5-2 steel drills, *Works by the Centre for Technical Development* 64 (1986) 211-216 (in Polish).
40. J. Adamczyk, K. Adamaszek, E. Hajduczek, H. Szymura, Effect of carbonitriding on the structure and properties of 18CrMnTi4-4 steel surface layers, *Proceedings of the Scientific and Technical Conference on Issues of Modern Thermochemical Treatment*, Warsaw, 1984, Vol. 1, 16-23 (in Polish).
41. J. Adamczyk, K. Adamaszek, E. Hajduczek, Effect of carbonitriding on the structure of surface layers and fatigue resistance of 18CrMnTi4-4 steel, *Proceedings of the 5<sup>th</sup> International Congress on Heat Treatment of Materials*, Budapest, Hungary, 1986, Vol. II, 759-766 (in Russian).

42. J. Adamczyk, E. Hajduczek, Microstructure of borided layer of Cr-Mo-V die steel, Proceedings of the 5<sup>th</sup> International Congress on Heat Treatment of Materials, Budapest, Hungary, 1986, Vol. II, 798-805 (in Russian).
43. L.A. Dobrzański, J. Adamczyk, E. Hajduczek, M. Czech, H. Słupik, Cutting ability tests of the drills after thermochemical treatments, Proceedings of the 1<sup>st</sup> International Scientific Conference "Achievements in the Mechanical and Material Engineering", Gliwice, 1992, Vol. 1, 29-34 (in German).
44. L.A. Dobrzański, J. Mazurkiewicz, E. Hajduczek, J. Madejski, Comparison of the thermal fatigue resistance and structure of the 47CrMoWVTiCeZr16-26-8 hot-work tool steel with X40CrMoV5-1 type one, Journal of Materials Processing Technology 113 (2001) 527-538.
45. M. Polok-Rubinić, L.A. Dobrzański, M. Adamiak, Comparison of the PVD coatings deposited onto plasma nitrided steel, Journal of Achievements in Materials and Manufacturing Engineering 42 (2010) 172-179.
46. L. Georghiou, J.C. Harper, M. Keenan, I. Miles, R. Popper (eds.), The Handbook of Technology Foresight. Concepts and Practice, Edward Elgar Publishing Ltd., UK, 2008.
47. L.A. Costanzo, R.B. Mackay, Handbook of Research on Strategy and Foresight, Edward Elgar Publishing, UK, 2009.
48. A.D. Dobrzańska-Danikiewicz, The methodological fundamentals of development state analysis of surface engineering technologies, Journal of Achievements in Materials and Manufacturing Engineering 40/2 (2010) 203-210.
49. A.D. Dobrzańska-Danikiewicz, Foresight of materials surface engineering as a tool stimulating sustainable development and to increase the quality of technology, Journal of Machine Engineering 10/3 (2010) 48-59.
50. The Boston Consulting Group, The Product Portfolio, Perspectives 66 (1970).
51. N. Gerdşri, R.S. Vatananan, S. Dansamasatid, Dealing with the dynamics of technology road-mapping implementation: A case study, Technical Forecasting & Social Change 76 (2009) 50-60.
52. Y. Yasunaga, M. Watanabe, M. Korenaga, Application of technology roadmaps to governmental innovation Policy for promoting technology convergence, Technical Forecasting & Social Change 76 (2009) 61-79.
53. R. Phaal, G. Muller, An architectural framework for roadmapping: Towards visual strategy, Technological Forecasting & Social Change 76 (2009) 39-49.
54. J.C.A. Batista, C. Godoy, V.T.L. Buono, A. Matthews, Characterisation of duplex and non-duplex (Ti, Al)N and Cr-N PVD coatings, Materials Science and Engineering A 336 (2002) 39-51.
55. I. Lee, I. Park, Microstructures and mechanical properties of surface-hardened layer produced on SKD 61 steel by plasma radical nitriding, Materials Science and Engineering A 449-451 (2007) 890-893.

56. K. Dybowski, Ł. Kaczmarek, R. Pietrasik, J. Smolik, Ł. Kołodziejczyk, D. Batory, M. Gzik, M. Stegliński, Influence of chemical heat treatment on the mechanical properties of paper knife-edge die, *Journal of Achievements in Materials and Manufacturing Engineering* 37/2 (2009) 422-427.
57. B. Podgornik, S. Hogmark, O. Sandberg, V. Leskovsek, Wear resistance and anti-sticking properties of duplex treated forming tool steel, *Wear* 254/11 (2003) 113-1121.
58. V.I. Shemegon, Surface hardening of twist drills, *Metal Science and Heat Treatment* 40/6 (1998) 243-249.
59. K. Genel, Boriding kinetics of H13 steel, *Vacuum* 80/5 (2006) 451-457.
60. B.S. Mann, Boronizing of cast martensitic chromium nickel stainless steel and its abrasion and cavitation-erosion behaviour, *Wear* 208/1-2 (1997) 125-131.
61. C. Martini, G. Palombarini, G. Poli, D. Prandstraller, Sliding and abrasive wear behaviour of boride coatings, *Wear* 256/6 (2004) 608-613.
62. S. Taktak, Tribological behaviour of borided bearing steels at elevated temperatures, *Surface & Coatings Technology* 201/6 (2006) 2230-2239.
63. M. Kulka, A. Pertek, Gradient formation of boride layers by borocarburing, *Applied Surface Science* 254/16 (2008) 5281-5290.
64. I. Gunes, S. Ulker, S. Taktak, Plasma paste boronizing of AISI 8620, 52100 and 440C steels, *Materials and Design* 32/4 (2011) 2380-2386.
65. M. Mathew, P.K. Rajendrakumar, Optimization of process parameters of boro-carburized low carbon steel for tensile strength by Taquchi method with grey relational analysis, *Materials and Design* 32/6 (2011) 3637-3644.
66. A.D. Dobrzańska-Danikiewicz, T. Tański, S. Malara, J. Domagała-Dubiel, Assessment of strategic development perspectives of laser treatment of casting magnesium alloys, *Archives of Materials Science Engineering* 45/1 (2010) 5-39.
67. A.D. Dobrzańska-Danikiewicz, E. Jonda, K. Labisz, Foresight methods application for evaluating laser treatment of hot-work steels, *Journal of Achievements in Materials and Manufacturing Engineering* 43/2 (2010) 750-773.
68. A.D. Dobrzańska-Danikiewicz, K. Lukaszewicz, Technology validation of coatings deposition onto the brass substrate, *Archives of Materials Science Engineering* 46/1 (2010) 5-38.
69. A.D. Dobrzańska-Danikiewicz, A. Drygała, Foresight methodology application for laser texturing of silicon surface, *Proceedings of Polish-Ukrainian Scientific Conference – Mechanics and Computer Science*, Chmielnicki, Ukraine, 2011, 156-157.
70. FORSURF. Structural project in realisation, [www.forsurf.pl](http://www.forsurf.pl) 2009-2012 (in Polish).