UDC 621.002.56

O. D. GRYSHKEVYCH, S. I. HRYNIUK

DEVELOPMENT OF PLASMA PROCESS DEVICES FOR A COMBINED TECHNOLOGY OF PARTS STRENGTHENING

Institute of Technical Mechanics
of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine
15 Leshko-Popel St., Dnipro 49005, Ukraine; e-mail: Gryshkevych.O.D@nas.gov.ua

The aim of this work is to develop plasma process devices and combinations thereof for the use in a process plant for the implementation of a combined process of metal parts working surface strengthening. All the component parts of the process plant meet progressivity criteria and can be mounted in the working chamber of a standard vacuum plant. Consideration is given to the features of the design and operation of plasma process devices constructed with the use of physical effects of the interaction of concentrated energy fluxes with the surface under treatment. To conduct ion-beam and ion-plasma treatment of the outer and inner surfaces of parts, several models of self-contained ion sources and magnetron sputtering systems have been developed, made, and tested. Consideration is given to the features of the functioning and destination of different construction arrangements of a vacuum-plasma plant for treatment of variously shaped parts. Recommendations are formulated on the choice of the optimum composition of process devices and construction arrangements of the vacuum-plasma plant for combined treatment of parts with inner and outer working surfaces.

Ключевые слова: *combined technology, ion-plasma technology, ion-beam technology, magnetron sputtering system, anode layer accelerator.*

1. *Gryshkevych O. D.* Development of a combined technology for parts strengthening (*in Russian*). Technical Mechanics. 2017. No. 3. Pp. 100–114.
2. *Baranov O. O., Sanochkin Yu. V.* Theory with a discharge with a closed electron drift (*in Russian*). Zhurnal Tekhnicheskoi Fiziki, 1974. No. 12. Pp. 2501–2516.
3. *Morozov A. I.* Introduction to Plasmadynamics (*in Russian*). Moscow: Fizmatgiz, 2006. 576 pp.
4. *Pleshivtsev N. V.* Cathode Sputtering (*in Russian*). Moscow: Atomizdat, 1968. 340 pp.
5. *Berish R.* Ion Bombardment Sputtering of Solids (*in Russian*). Moscow: Mir, 1984. 336 pp.
6. *Gabovich M. D.* Physics and Technology of Plasma Ion Sources (*in Russian*). Moscow: Atomizdat, 1972. 304 pp.
7. *Danilin B. S.* Magnetron Sputtering Systems (*in Russian*). Moscow: Radio i Svyaz, 1982. 72 pp.
8. *Kuzmichev A. I.* Magnetron Sputtering Systems (*in Russian*). Kyiv: Avers, 2008. 244 pp.
9. *Kouznetsov V., Masak R., Schneider J. M. Ytlmersson U. Petrov I.* A novel pulsed magnetron sputter technique utilizing very high target paver densities. Surface and Coating Technology. 1999. No. 2 – 3. Pp. 290–293.
10. *Mozgrin D. V.* Experimental study of high-current forms of a low-pressure quasi-steady-state discharge in a magnetic field (*in Russian*). Fizika Plazmy. 1995. No. 5. Pp. 422–433.
11. *Levchuk D.* Plasma assisted techniques for deposition of super hard nanocomposite coatings. Surface and Coating Technology. 2007. No. 2007. Pp. 6071–6077.
12. *Musil J., Ŝuna J.* The role of energy in formation of sputtered nanocomposite films. Mater. Scien. Forum. – 2005. V. 502. Pp. 291–296.
13. *Window B. Savvides N.* Unbalanced magnetrons as sources of high ion fluxes. J. Vac. Sci. Tecnol A. 1986. No. 3. Pp. 453–465.
14. *Gryshkevych O. D., Hryniuk S. I.* Study of the imbalance characteristics of a planar magnetron sputtering system (*in Russian*). Problems in High-Temperature Technology. 2012. Pp. 45–52.
15. *Zharinov A. V., Popov Yu. S.* On plasma acceleration by a closed Hall current (*in Russian*). Zhurnal Tekhnicheskoi Fiziki. 1957. No. 2. Pp. 63–70.
16. *Garkusha V. I., Leskov L. V., Lyapin E. A.* Anode Layer Plasma Accelerators (*in Russian*). Moscow: Nauka. 1984. Pp. 129–138.
17. *Vinogradov M. I., Maishev Yu. P.* Vacuum Processes and Equipment of Ion- and Electron-Beam Technology (*in Russian*). Moscow: Mashinostroyeniye, 1989. 53 pp.
18. *Zhurin V. V.* Industrial Ion Sources: Broadbeam Gridless Ion Source Technology. Published 2012 by Wiley-VCH Verlag GmbH & Co. KGaA. Pp. 311.
19. Ion Sources with a Closed Electron Drift (*in Russian*). URL: http;// www.pronica/ru.htm/
20. *Dukhopelnikov D. V., Yurchenko A. A.* Experimental study of an anode layer process accelerator (*in Russian*). Vestnik MGTU im. N. E. Baumana, Ser. Mashinostroyeniye. 2004. No. 3. Pp. 74–83.
21. *Goncharov A. A., Dobrovolsky A. N., Pavlov S. N.* Anode layer plasma accelerator for material surface treatment *(in Russian*). Problemy Atomnoi Mauki i Tekhnologii. Seriya Fizika. 2000. No. 6. Pp. 160–163.
22. *Gryshkevych O. D., Khitko A. V.* Use of a plasma electron source in magnetron ion sputtering system (*in Russian*). Problems in High-Temperature Technology. 2011. Pp. 42–45.
23. *Bizyukov A. A., Girka A. I., Sereda K. N. et al.* Hall ion source with ballistic and magnetic beam focusing. Problems of Atomic Science and Technology. 2008. No. 6. Pp. 174–176.

24. *Marakhtanov M. K., Dukhotelnikov D. V., Ivakhnenko D. V.* Elektronny Nauchno-Tekhnichesky Zhurnal MVTU im. N. E. Baumana. Pp. 219 – 232. URL: http://www technomag.doc/edu/ru/doc/483944.html.
25. *Morozov A. I.* Focusing of cold quasi-neutral beams in electromagnetic fields (*in Russian*). Doklady Akademii Nauk SSSR. 1965. No. 6. Pp. 1363–1373.
26. *Gabovich M. D., Pleshivtsev N. V., Semashko N. N*. Ion and Atom Beams for Controlled Fusion and Technological Purposes (*in Russian*). Moscow: Energoatomizdat, 1986. 248 pp.
27. Patent for Utility Model Ukraine No. 38845U, IPC[6] C23C14/00. Plasma device (*in Ukrainian*). Filed on July 1, 2008. Published on January 26, 2009, Bul. No. 1, 4 pp.
28. *Berlin E. V., Seydman L. A.* Ion-Plasma Processes in Thin-Film Technology (*in Russian*). Moscow: Tekhnosfera, 2011. 528 pp.
29. *Gryshkevych O. D., Hryniuk S. I., Kovalenko V. V., Kuchuhurnyi Yu.P*. Process plasma devices based on a discharge with a closed electron drift. Development and Application (*in Russian*). Tekhnicheskaya Mekhanika. 2013. No. 4. Pp. 43–57.
30. *Rogov A. V., Kapustin Yu. V., Martynenko Yu. V.* Factots governing magnetron sputtering efficiency (*in Russian*). Zhurnal Tekhnicheskoi Fiziki. 2015. No. 85, Pp. 126–134.
31. Patent for Utility Model Ukraine No. 93471: IPC[6] C23C 14/00. Ion-plasma plant (*in Ukrainian*). Filed on May 11, 2010. Published on February 10, 2011, 3 pp.
32. Patent for Utility Model Ukraine No. 89038. IPC[6] C23C 14/00. Integrated-type ion-plasma device for inner surface treatment (*in Ukrainian*). Filed on October 28, 2013. Published on April 10, 2014, Bul. No. 7, 4 pp.
33. *Svadkovsky I. V.* Lines of development of magnetron sputtering systems (*in Russian*). Doklady BGUIR. 2007. No. 2(18). Pp. 112–121.
34. Patent for Utility Model Ukraine No. 102744, IPC[6] C23C14/00. Unbalanced cylindrical magnetron sputtering system (*in Ukrainian*). Filed on October 28, 2013. Published on November 25, 2015, Bul. No. 22, 5 pp.