**The use of the plasma VUV emission in photochemistry and biology**

G.Zvereva

*SOI, St-Petersburg. Russia*

*email: zvereva@soi.spb.ru*

The vacuum ultraviolet (VUV) radiation (10-200 nm) are emitted both by the artificially created plasma sources - gas discharge lamps, and by natural one - cosmic plasma. The most effective artificially created VUV light source (emission efficiency as high as 60% [1]) are dielectric barrier discharges in inert gases [2]. Sources of this type emit in the range 120-180 nm in consequence bound-free transitions of diatomic excimer molecules of inert gases. Natural sources of VUV radiation is a space hydrogen plasma. Accordingly, the effect of the VUV radiation generated by the plasma sources has a technical and biological significance both on Earth and in space.

One of the new technologies based on VUV sources is the use of them for production of highly reactive radicals. It is known that the VUV radiation is effectively absorbed by the water molecules and oxygen [3-5], resulting in the formation of reactive oxygen species (ROS) (•OH, $H_2O_2$, $HO_2$•, $OH^-$, etc.). Modern oxidation technologies, based on advanced oxidation processes (AOP) is used for the decomposition of organic pollutants in water and gases mainly •OH radicals [6,7]. Currently, VUV radiation is widely used in industry for cleaning surfaces in the manufacture of flat panel displays, and in the semiconductor industry in the manufacture of printed circuit boards [8]. Among the possible applications of ROS include: oxidative technologies [6,7], environmental non-abrasive polishing [9], exposure to biological tissues, disinfection [10,11].

VUV radiation is effectively absorbed by biological molecules : VUV irradiation of DNA leads to single and double-strand breaks, DNA modification [12-14]. Destruction of molecules can occur as a consequence of direct absorption of VUV photons and by the reactive VUV photolysis products. The mechanisms of the VUV effect on DNA are important in studies of mutagenesis and carcinogenesis.

The study of the VUV impact on microorganisms is of fundamental importance in terrestrial conditions (identifying mechanisms, disinfection) and of direct practical importance in space (astrobiology). Inactivation of microorganisms by VUV irradiation can take place in two main ways: by the destruction of the DNA [13, 15] and by the destruction of the cell membrane [16]. Both of these mechanisms, in turn, may be implemented as a direct consequence of the absorption of the VUV photons [17-19], and as a result of effect of reactive water VUV photolysis products [20, 21]. Conducting experiments on microorganisms VUV irradiation is

technically complicated, so to this issue is devoted a small number of works. Among them is the series of studies [16,22,23], in which spores of microscopic fungi *Saccharomyces cerevisiae* were irradiated. The authors concluded that the VUV inactivation mechanism of wet spores associated with the destruction of the cell membrane by highly reactive products VUV photolysis. It should be noted, that one of the most suitable for astrobiological research microorganisms are microscopic fungi isolated from Antarctic habitat [24,25], which have developed resistance to low temperatures, high UV emission doses and radiation.

Thus, the study of the impact of the VUV radiation generated by the plasma sources, has a wide topicality: the results are applicable both in the earthly conditions (cleaning and modification of surfaces, highly reactive radicals production, disinfection, research of mutagenesis and carcinogenesis) and in space (space materials science, astrobiology).

**References**

[1] F.Vollkommer and L.Hitzschke, *Proceedings of the 8th International Symposium on the Science and Technology of Light Sources)*, Greifswald,,Germany, p.51-60, (1998).

[2] G.Volkova, N.Kirillova, E.Pavlovskaya and I.Podmoshenskiy, Bill. Izovr. Tov. Zn.1982.N41. p.179 (rus).

[3] Heit G., Neuner A., Saugy P.-Y., Braun A.M. , Vacuum-UV (172 cm) Actinometry. The Quantum Yield of the Photolysis of Water// J. Chem. Phys. A, v.102, pp.5551-5561, (1998).

[4] K.Watanabe and M.Zelikoff, Absorption Coefficient of Water Vapor in the Vacuum Ultraviolet// J. Opt. Soc. Am., v.43, N9, pp.753-755, (1953).

[5] Watanabe K., Inn E.C.Y. and Zelikoff M., Absorption Coefficients of Oxygen in the Vacuum Ultraviolet // Chem. Phys., N6, pp.1026-1030, (1953).

[6] Oppenlander Th. Photochemical Purification of Water and Air. Wiley-VCH, 2003.Weinheim. 368 p.

[7] Handbook of Environmental Engineering // ed. By Wang L.K., Hung Y.-T. and Shammas N.K. Human Press Inc. NY. 2006. 481p.

[8] Morimoto Y., Sumitomo T., Yoshioka M., Takemura T. Resent progress on UV lamps for industries // Proc. of IAS (IEEE Industry application society), 2004. C.24-31.

[9] Kirino O. and Enomoto T. Ultra-flat and ultra-smooth Cu surfaces produced by abrasive-free chemical-mechanical planarization/polishing using vacuum ultraviolet light// Precision Engineering. 2011. V.35. C.669-676

[10] Weltmann K.D., Kindel E., Woedtke T., Hähnel M., Stieber M., and Brandenburg R. Atmospheric-pressure plasma sources: Prospective tools for plasma medicine// Pure Appl. Chem. 2010. V.82, p.1223-1237.

[11] Kalghatgi S., Kelly C.M., Cerchar E., Torabi B., Alekseev O., Fridman A., Friedman G., Azizkhan-Clifford J. Effects of Non-Thermal Plasma on Mammalian Cells// PLos One.2011. V.6(1), P.1-11.

[12] Voet D., Gratzer W.B., Cox R.A. and Doty P., Absorption spectra of nucleotides, polynucleotides, and nucleic acids in the far ultraviolet// Biopolymers, v.1, pp.193-208,(1963).

[13] N.Munakata, K.Hieda, K.Kobayashi, A.Ito and T.Ito, *Photochem. Photobiol.* , v.44, pp.385, (1986).

[14] B. D. Michael , K. M. Prise, M. Folkard, B . Vojnovic,B. Brocklehurst, I . H. Munro and A. Hopkirk ,Int. J. Radiat. Biol., 1994, v . 66, N5, pp. 569-572.

[15]N.Ya.Dodonova, M.N.Kiseleva, L.A.Remisova and N.M.Tsyganenko, *Photochemistry and Photobiology*, v.35, pp.129-132, (1982).

[16] K.Hieda, K.Kobayashi, A.Ito and T.Ito, *Radiation Research*, v.98, pp.74-81,(1984).

[17] W. H. Nosal, D. W. Thompson,T. E. Tiwald,S. Sarkar, A. Subramanian, and J. A. Woollam, Vacuum ultraviolet optical analysis of spin-cast chitosan films modified by succinic anhydride and glycidyl phenyl ether *Surface and Interface Analysis* **39** (2007), pp. 747–751

[18] H.R. Dickinson and W.C.Johnson, Optical properties of Sugars. II. Vacuum-Ultraviolet Absorption of Model Compounds// J.Am. Chem. Soc., v.96, N16, pp.5050-5054.

[19] J.Kumirska, M.Czerwicka, Z.Kaczyński, A. Bychowska, K. Brzozowski, J. Thöming and P. Stepnowski, Mar. Drugs, v.8, pp.1567-1636 (2010).

[20] N.Ya.Dodonova, M.N.Kiseleva, L.A.Remisova and N.M.Tsyganenko, The Vacuum ultraviolet chemistry of nucleotides// Photochem. Photobiol., v.35, pp.129-132, (1982).

[21] J. Duan and D. L. Kasper, Oxidative depolymerization of polysaccharides by reactive oxygen/nitrogen species, Glycobiology vol. 21 no. 4 pp. 401–409, 2011

[22] T.Ito, A.Ito, K.Hieda and K.Kobayashi, *Radiation Research*, v.96, pp.532-548,(1983).

[23] T.Ito and A.Ito, *Radiation Research*, v.85, pp.161-172,(1981).

[24] S. Onofri, D. Barreca, L. Selbmann, D. Isola, E. Rabbow, G. Horneck, J.P.P. de Vera, J. Hatton and L. Zucconi, Resistance of Antarctic black fungi and cryptoendolithic communities to simulated space and Martian conditions//Studies in Mycology 61: 99-109.2008

[25] G. Zvereva, I. Kirtsideli, A.Saifitdinova, S.Galkina, A. Parfenov, N. Grigoryeva, Effect of VUV radiation of rare gas barrier discharge plasma on microfungi, Books of Contributions of HAKONE XIV (14th International Symposium on High Pressure Low Temperature Plasma Chemistry), p.571-575, September 21-26, 2014, Zinnowitz, Germany.