Pure and Applied Chemistry 2017 vol.89 N10, pages 1471-1490

# Electrochemical DNA sensors based on spatially distributed redox mediators: Challenges and promises

Evtugyn G., Porfireva A., Stoikov I.
*Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia*

## Abstract

© 2017 IUPAC & De Gruyter. DNA and aptasensors are widely used for fast and reliable detection of disease biomarkers, pharmaceuticals, toxins, metabolites and other species necessary for biomedical diagnostics. In the overview, the concept of spatially distributed redox mediators is considered with particular emphasis to the signal generation and biospecific layer assembling. The application of non-conductive polymers bearing redox labels, supramolecular carriers with attached DNA aptamers and redox active dyes and E-sensor concept are considered as examples of the approach announced.

http://dx.doi.org/10.1515/pac-2016-1124

## Keywords

aptasensor, DNA damage, DNA sensor, E-sensor, mediated electron transfer, Mendeleev XX, pillar[5]arene, thiacalix[4]arene

## References

[1] V. Perumal, U. Hashim. J. Appl. Biomed. 12, 1 (2014
[2] N. Thiyagarajan, J.-L. Chang, K. Senthilkumar, J.-M. Zen. Electrochem. Commun. 38, 86 (2014
[3] S.K. Vashist, D. Zheng, K. Al-Rubeaan, J.H.T. Luong, F.-S. Sheu. Anal. Chim. Acta. 703, 124 (2011
[4] E. Y. Jomma, S.-N. Dong. Curr. Anal. Chem. 12, 5 (2016
[5] C. R. Ispas, G. Crivat, S. Andreescu. Anal. Lett. 45, 168 (2012
[6] A. Chaubey, B. D. Malhotra. Biosens. Bioelectron. 17, 441 (2002
[7] L. Murphy. Curr. Opin. Chem. Biol. 10, 177 (2006
[8] M. Ongaro, P. Ugo. Anal. Bioanal. Chem. 405, 3715 (2013
[9] S. V. Dzyadevych, V. N. Arkhypova, A. P. Soldatkin, A. V. Elskaya, C. Martelet, N. Jaffrezic-Renault. ITBM-RBM 29, 171 (2008
[10] T. Tatsuma, T. Watanabe. Anal. Chem. 64, 625 (1992
[11] E. Katz, V. Heleg-Shabtai, B. Willner, I. Willner, A. F. Buckmann. Bioelectrochem. Bioenerg. 42, 95 (1997
[12] J. Wang, Chem. Rev. 108, 814 (2008
[13] P. Das, M. Das, S. R. Chinnadayyal, I. M. Singh, P. Goswami. Biosens. Bioelectron. 79, 386 (2016
[14] R. R. Costa, J. F. Mano. Chem. Soc. Rev. 43, 3453 (2014
[15] E. Katz, I. Willner. Electroanalysis. 15, 913 (2003
[16] F. Jelen, M. Fojta, E. Palecek. J. Electroanal. Chem. 427, 49 (1997
[17] X. Cai, G. Rivas, P. A. M. Farias, H. Shiraishi, J. Wang, M. Fojta, E. Palecek. Bioelectrochem. Bioenerg. 40, 41 (1996

[18] E. Palecek. Talanta 56, 809 (2002
[19] F. Lucarelli, I. Palchetti, G. Marazza, M. Macini. Talanta 56, 949 (2002
[20] J. Wang, G. Rivas, X. Cai, E. Paleček, P. Nielsen, H. Shiraish, N. Dontha, D. Luo, C. Parrado, M. Chicharro, P. A. M. Farias, E. S. Valera, D. H. Grant, M. Ozsoz, M. N. Flair. Anal. Chim. Acta 347, 1 (1997
[21] A. Mugweru, J. F. Rusling. Electrochem. Commun. 3, 406 (2001
[22] A. Mugweru, J. F. Rusling. Anal. Chem. 74, 4044 (2002
[23] H. H. Thorp. Trends Biotechnol. 16, 117 (1998
[24] B. Wang, J. F. Rusling. Anal. Chem. 75, 4229 (2003
[25] A. Mugweru, B. Wang, J. Rusling. Anal. Chem. 76, 5557 (2004
[26] L. Dennany, R. J. Forster, J. F. Rusling. J. Am. Chem. Soc. 125, 5213 (2003
[27] J. Yang, B. Wang, J. F. Rusling. Mol. BioSyst. 1, 251 (2005
[28] M. Tarun, J. F. Rusling. Anal. Chem. 77, 2056 (2005
[29] A. Mugweru, J. F. Rusling. Electroanalysis 18, 327 (2006
[30] B. Song, M. Shen, D. Jiang, S. Malla, I. M. Mosa, D. Choudhary, J. F. Rusling. Analyst 141, 5722 (2016
[31] J. P. Tosar, G. Branas, J. Laiz. Biosens. Bioelectron. 26, 1205 (2010
[32] E. G. Hvastkovs, D. A. Buttry. Analyst 135, 1817 (2010
[33] K. Chang, S. Deng, M. Chen. Biosens. Bioelectron. 66, 297 (2015
[34] A. Liu, J. Anzai. Anal. Chem. 76, 2975 (2004
[35] P. Kavanagh, D. Leech. Anal. Chem. 78, 2710 (2006
[36] X. Li, J. Xia, S. Zhang. Anal. Chim. Acta 622, 104 (2008
[37] S. Reisberg, B. Piro, V. Noel, M. C. Pham. Anal. Chem. 77, 3551 (2005
[38] B. Piro, J. Haccoum, M. C. Pham, L. D. Tran, A. Rubin, H. Perrot, C. Gabrielli. J. Electroanal. Chem. 577, 155 (2005
[39] G. Evtugyn, T. Hianik. TrAC Trends Anal. Chem. 79, 168 (2016
[40] H. C. Budnikov, G. A. Evtugyn, A. V. Porfireva. Talanta 102, 137 (2012
[41] Md. M. Rahman, X.-B. Li, N. S. Lopa, S. J. Ahn, J.-J. Lee. Sensors 15, 3801 (2015
[42] K. Habermuller, M. Mosbach, W. Schuhmann. Fresenius J. Anal. Chem. 366, 560 (2000
[43] A. Ramanavičius, A. Ramanavičiene, A. Malinauskas. Electrochim. Acta. 51, 6025 (2006
[44] A. Walcarius. Chem. Soc. Rev. 42, 4098 (2013
[45] A. Walcarius. Electroanalysis 27, 1303 (2015
[46] R. Ludwig. Microchim. Acta 152, 1 (2005
[47] T. Ogoshi, T. Yamagishi. Eur. J. Org. Chem. 2961 (2013
[48] S. Yang, M. Uoy, L. Yang, F. Zhang, Q. Wang, P. He. J. Electroanal. Chem. 783, 151 (2016
[49] T. Ogoshi, S. Kanai, S. Fujinami, T. Yamagishi, Y. Nakamoto. J. Am. Chem. Soc. 130, 5022 (2008
[50] D.-W. Lee, K. M. Park, B. Gong, D. Shetty, J. K. Khedkar, K. Baek, J. Kim, S. H. Ryu, K. Kim. Chem. Commun. 51, 3098 (2015
[51] C. A. Holland, A. T. Henry, H. C. Whinna, F. C. Church. FEBS Lett. 484, 87 (2000
[52] L. C. Bock, L. C. Griffin, J. A. Latham, E. H. Vermaas, J. J. Toole. Nature. 355, 564 (1992
[53] C. Tuerk, L. Gold. Science 249, 505 (1990
[54] D.M. Tasset, M.F. Kubik, W. Steiner. J. Mol. Biol. 272, 688 (1997
[55] G. Evtugyn, V. Kostyleva, R. Sitdikov, A. Porfireva, M. Savelieva, I. Stoikov, I. Antipin, T. Hianik. Electroanalysis. 24, 91 (2012
[56] G. A. Evtugyn, V. B. Kostyleva, A. V. Porfireva, M. A. Savelieva, V. G. Evtugyn, R. R. Sitdikov, I. S. Antipin, T. Hianik. Talanta. 102, 156 (2012
[57] G. Evtugyn, A. Porfireva, A. Ivanov, O. Konovalova, T. Hianik. Electroanalysis 21, 1272 (2009
[58] A. V. Porfireva, G. Evtugyn, A. N. Ivanov, T. Hianik. Electroanalysis 22, 2187 (2010
[59] M. Peraica, B. Radić, A. Lucić, M. Pavlović. WHO Bull. 77, 754 (1999
[60] M. Z. Zheng, J. L. Richard, J. Binder. Mycopathologia 161, 261 (2006
[61] 56th Report of the Joint FAO/WHO Expert Committee on Food Additives, WHO Technical Report Series 906, Geneva, Switzerland, 70 (2002
[62] G. Evtugyn, A. Porfireva, V. Stepanova, R. Sitdikov, I. Stoikov, D. Nikolelis, T. Hianik. Electroanalysis 26, 2100 (2014

[63] G. Evtugyn, A. Porfireva, R. Sitdikov, V. Evtugyn, I. Stoikov, I. Antipin, T. Hianik. Electroanalysis 25, 1847 (2013
[64] G. Castillo, I. Lamberti, L. Mosiello, T. Hianik. Electroanalysis 24, 512 (2012
[65] F.-C. Loo, S.-P. Ng, C.-M.L. Wu, S.K. Kong. Sens. Actuators B 198, 416 (2014
[66] G.-X. Wang, Z. Yang, Z.-H. Li, B.-T. Zhao. Anal. Lett. 48, 982 (2015
[67] X. Fuku, F. Iftikar, E. Hess, E. Iwuoha, P. Baker. Anal. Chim. Acta 730, 49 (2012). 49
[68] V. B. Stepanova, D. N. Shurpik, V. G. Evtugyn, I. I. Stoikov, G. A. Evtugyn, Yu N. Osin, T. Hianik. Sens. Actuators B 225, 57 (2016
[69] R. Pauliukaite, C. M. A. Brett. Electroanalysis 20, 1275 (2008
[70] R. V. Shamagsumova, D. N. Shurpik, P. L. Padnya, I. I. Stoikov, G. A. Evtugyn. Talanta 144, 559 (2015
[71] V. Smolko, D. Shurpik, V. Evtugyn, I. Stoikov, G. Evtugyn. Electroanalysis 28, 1391 (2016
[72] V. B. Stepanova, D. N. Shurpik, V. G. Evtugyn, I. I. Stoikov, G. A. Evtugyn, T. Hianik. J. Anal. Chem. 72, 375 (2017
[73] C. Fan, K. W. Plaxco, A. J. Heeger. Proc. Natl. Acad. Sci. USA 100, 9134 (2003
[74] R. Y. Lai, E. T. Lagally, S. Lee, H. T. Soh, K. W. Plaxco, A. J. Heeger. Proc. Natl. Acad. Sci. USA 103, 4017 (2006
[75] L. Feng, W. Li, J. Ren, X. Qu. Nano Research 8, 887 (2015
[76] F. Ricci, R. Y. Lai, A. J. Heeger, K. W. Plaxco, J. J. Sumner. Langmuir 23, 6827 (2007).47
[77] C. E. Immoos, S. J. Lee, M. W. Grinstaff. J. Am. Chem. Soc. 126, 10814 (2004
[78] D. Kang, X. Zuo, R. Yang, F. Xia, K. W. Plaxco, R. J. White. Anal. Chem. 81, 9109 (2009
[79] D. Kang, F. Ricci, R. J. White, K. W. Plaxco. Anal. Chem. 88, 10452 (2016
[80] A. A. Lubin, R. Y. Lai, B. R. Baker, A. J. Heeger, K. W. Plaxco. Anal. Chem. 78, 5671 (2006
[81] E. Farjami, L. Clima, K. Gothelf, E. E. Ferapontova. Anal. Chem. 83, 1594 (2011
[82] L. Kékedy-Nagy, S. Shipovskov, E. E. Ferapontova. Anal. Chem. 88, 7984 (2016
[83] G. Chatelain, M. Ripert, C. Farrem S. Ansanay-Alex, C. Chaix. Electrochim. Acta 59, 57 (2012
[84] A. Miodek, N. Mejri, M. Gomgnimbou, C. Sola, H. Korri-Youssoufi. Anal. Chem. 87, 9257 (2015
[85] Y. Xiao, X. Qu, K. W. Plaxco, A. J. Heeger. J. Am. Chem. Soc. 129, 11896 (2007
[86] B. Jiang, F. Li, C. Yang, J. Xie, Y. Xiang, R. Yuan. Anal. Chem. 87, 3094 (2015
[87] F. Gao, L. Du, D. Tang, Y. Du. Anal. Chim. Acta 883, 67 (2015
[88] Y. Du, B. J. Lim, B. Li, Y. S. Jiang, J. L. Sessler, A. D. Ellington. Anal. Chem. 86, 8010 (2014
[89] J. Xu, Q. Wang, Y. Xiang, R. Yuan, Y. Chai. Analyst 139, 128 (2014
[90] X. Mao, J. Jiang, X. Xu, X. Chu, Y. Luo, G. Shen, R. Yu Biosens. Bioelectron. 23, 1555 (2008
[91] G. Liu, Y. Wan, V. Gau, J. Zhang, L. Wang, S. Song, C. Fan. J. Am. Chem. Soc. 130, 6820 (2008
[92] F. Li, Y. Xu, X. Yu, Z. Yu, H. Ji, Y. Song, H. Yan, G. Zhang. Sens. Actuators B. 234, 648 (2016
[93] X. Yu, Z. Yu, F. Li, Y. Xu, X. He, L. Xu, W. Shi, G. Zhang, H. Yan. Biosens. Bioelectron. 91, 817 (2017
[94] L. Feng, B. Xu, J. Ren, C. Zhao, X. Qu, Chem. Commun. 48, 9068 (2012
[95] Y. Xiao, T. Uzawa, R. J. White, D. DeMartini, K. W. Plaxco. Electroanalysis 21, 126 (2009
[96] E. E. Ferapontova, K. V. Gothelf. Electroanalysis 21, 1261 (2009
[97] J. S. Swensen, Y. Xiao, B. S. Ferguson, A. A. Lubin, R. Y. Lai, A. J. Heeger, K. W. Plaxco, H. T. Soh. J. Am. Chem. Soc. 131, 4262 (2009
[98] J. Gerasimov, C. S. Schaefer, W. Yang, R. L. Grout, R. Y. Lai. Biosens. Bioelectron. 42, 62 (2013
[99] S. Zhao, W. Yang, R. Y. Lai. Biosens. Bioelectron. 26, 2442 (2011
[100] M. Shamsipur, L. Farzin, M. A. Tabrizi, F. Molaabasi. Biosens. Bioelectron. 74, 369 (2015
[101] J. C. Cunningham, N. J. Brenes, R. M. Crooks. Anal. Chem. 86, 6166 (2014
[102] T. Bao, W. Wen, X. Zhang, S. Wang. Anal. Chim. Acta 860, 70 (2015
[103] S. Su, H. Sun, W. Cao, J. Chao, H. Peng, X. Zuo, L. Yuwen, C. Fan, L. Wang. ACS Appl. Mater. Interfaces. 8, 6826 (2016
[104] L.-D. Li, Z.-B. Chen, H.-T. Zhao, L. Guo, X. Mu. Sens. Actuators B. 149, 110 (2010
[105] J. Xia, D. Song, Z. Wang, F. Zhang, M. Yang, R. Gui, L. Xia, S. Bi, Y. Xia, Y. Li, L. Xia. Biosens. Bioelectron. 68, 55 (2015
[106] L. Wu, X. Zhang, W. Liu, E. Xiong, J. Chen. Anal. Chem. 85, 8397 (2013
[107] M. Souada, B. Piro, S. Reisberg, G. Anquetin, V. Noel, M. C. Pham. Biosens. Bioelectron. 68, 49 (2015
[108] L. Wu, J. Ren, X. Qu. Nucleic Acids Research, 42, e160 (2014

[109] L. Wu, H. Ji, H. Sun, C. Ding, J. Ren, X. Qu. Chem. Commun. 52, 12080 (2016