IOP Conf. Series: Materials Science and Engineering **98** (2015) 012019 doi:10.1088/1757-899X/98/1/012019

Membrane materials for storing biological samples intended for comparative nanotoxicological testing

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Abstract. The study is aimed at identifying the samples of most promising membrane materials for storing dry specimens of biological fluids (Dried Blood Spots, DBS technology). Existing sampling systems using cellulose fiber filter paper have a number of drawbacks such as uneven distribution of the sample spot, dependence of the spot spreading area on the individual biosample properties, incomplete washing-off of the sample due to partially inconvertible sorption of blood components on cellulose fibers, etc. Samples of membrane materials based on cellulose, polymers and glass fiber with applied biosamples were studied using methods of scanning electron microscopy, FT-IR spectroscopy and surface-wetting measurement. It was discovered that cellulose-based membrane materials sorb components of biological fluids inside their structure, while membranes based on glass fiber display almost no interaction with the samples and biological fluid components dry to films in the membrane pores between the structural fibers. This characteristic, together with the fact that membrane materials based on glass fiber possess sufficient strength, high wetting properties and good storage capacity, attests them as promising material for dry samples of biological fluids storage systems.

1. Introduction

In 1963 a Scottish scientist Robert Guthrie introduced into practice diagnostics of phenylketonuria in newborn infants by analyzing blood samples dried-up on sheets of porous cellulose paper [1]. Since then this method of sample preparation (DriedBloodSpots or DBS) gained wide popularity in many countries for so called neonatal screening of infants. In spite of large-scale application of the approach, based on obtaining dried blood spots for neonatal screening, by specialists in many countries, it is only in recent times that we see increase in the number of works where DBS technology is applied not only in medical diagnostics, but also in such areas as veterinary, pharmacokinetic studies, genetic diagnostics, creating specialized data banks, etc. [2, 3, 4]. Drawbacks of the existing sampling systems using cellulose fiber filter paper are: uneven distribution of the sample spot, dependence of the spot spreading area on the individual biosample properties, incomplete washing-off of the sample due to partially inconvertible sorption of blood components on cellulose fibers, etc. That is why studies aimed at discovering new materials for collecting and storing biological samples, including samples for nanotoxicological research, seem so promising.

2. Research target and methods

Research target. The work studied characteristics of the following membranes: cellulose membrane TFN («Munktell», Germany); glass fiber membrane 8964 («Ahlstrom», USA) and glass fiber membrane GFSP 223000 («Millipore», USA), as presented in the Table 1.

Table 1. Membrane materials

Denomination	Membrane	Chemical composition
Paper 01 (P01)	CFSP223000 Lot 92072701	Cellulose fiber
Paper 02 (P02)	CFCP203000 Lot 92073601	Glass fiber
Paper 03 (P03)	MAPDS-0300 Lot 4072402 (Grade 8964)	Glass fiber
Paper 04 (P04)	TFN 179 г/см2 Lot 11156	Cellulose fiber
Paper 05 (P05)	Grade 111 102170	Cotton fiber
Paper 06 (P06)	Grade 121 102168	Cotton fiber
Paper 07 (P07)	Grade 142 102563	Cotton fiber
Paper 08 (P08)	Grade 1281 102446	Cellulose fiber
Paper 09 (P09)	Grade 6613 Lot 496651	Polymer fiber
Paper 10 (P10)	Grade Lot091061	Polymer fiber
Paper 11 (P11)	Grade 8950 Lot 106951	Glass fiber
Paper 12 (P12)	Grade 8951 Lot 106951	Glass fiber
Paper 13 (P13)	Grade 8964 Lot 100791	Glass fiber
Paper 14 (P14)	Grade 320 Lot 102674	Cotton fiber
Paper 15 (P15)	Grade 222 Lot 106671	Cotton fiber
Paper 16 (P16)	Grade 237 Lot 101461	Cotton fiber
Paper 17 (P17)	Grade 238 Lot 101666	Cotton fiber
Paper 18 (P18)	Grade 319 Lot 102464	Cotton fiber
Paper 19 (P19)	Grade 601 Lot 102915	Cotton fiber
Paper 20 (P20)	Grade 270 Lot 102741	Cotton fiber
Paper 21 (P21)	CytoSep 1660 Lot 8290501	Mix of natural and synthetic fibers
Paper 22 (P22)	CytoSep 1663 Lot 829053	Mix of natural and synthetic fibers

Research methods. In order to study the properties of membranes after biological fluid application, samples about 5 mm on a side were impregnated with blood serum by dipping the membranes into a biosample till complete saturation with subsequent air drying at room temperature.

The membrane material samples were studied by methods of scanning electron microscopy (scanning electron microscope JEOLJSM-6610LV, «JEOL», Japan), angle of wetting analysis (equipment KRUSSEASYDROP, «KRÜSS», Germany), mechanical tension testing (universal testing machine Zwick/Roellz020, «Zwick», Germany), surface composition analysis by means of FT-IR spectroscopy (FT-IR spectrometer Nicolet 380, «Thermo Scientific», USA).

3. Results and discussion

It was discovered that membranes based on cellulose materials tend to sorb components of the biological fluid inside their structure, while membranes based on glass fiber display almost no interaction with the samples and biological fluid components dry to films in the membrane pores between the structural fibers (Figure 1).

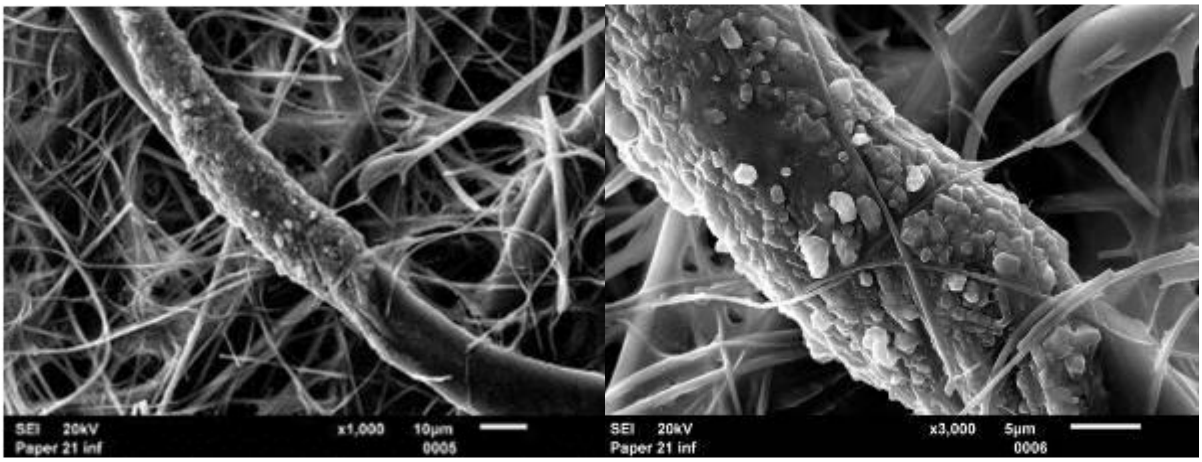

Figure 1. Microphotograph of a P21 sample (mix of natural and synthetic fibers) presenting an area with the urea layer on fiberglass (a) and urea crystal in and on cellulose fiber materials (b)

In addition it has been discovered that the samples of glass fiber membranes possess the highest strength among the studied samples, therefore they can withstand higher external mechanical stresses. Also it has been shown that glass fiber membranes require thrice less time for soaking than cellulose ones, which makes them more convenient for sampling biological fluids by application to a thin stripe of membrane material. Such characteristics as capillary rise and specific volume of glass fiber membranes are also higher than those of cellulose-based samples.

4. Conclusions

It has been proved that cellulose-based membranes sorb components of biological fluids inside their structure, while membranes based on glass fiber display almost no interaction with the samples and biological fluid components dry to films in the membrane pores between the structural threads. This characteristic, together with the fact that membrane materials based on glass fiber possess sufficient strength, high wetting properties and good storage capacity, attests them as a promising material for storage systems for dry samples of biological fluids.

Acknowledgments

The authors gratefully acknowledge the financial support of the Ministry of Education and Science of the Russian Federation within the Federal Target Program “Research and development on priority directions of scientific-technological complex of Russia in 2014-2020” (project No. RFMEFI57814X0010).

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