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ON BEHAVIOUR OF PVB SOLUTIONS IN ELECTROSPINNING

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Summary: *This contribution aims at a determination of dependence of shear viscosity of polyvinylbuthyral (PVB) on the intensity of electric field to which PVB solutions are exposed. It was found that the viscosity ratio* η/η_0 *(where* η *and* η_0 *are the viscosities of a solution in presence and absence of electric field, respectively) depends on the polarity of solvent. This pre-determines the possibility of application of the individual solvents for the process of electrospinning.*

1. Introduction

The process of electrospinning is based on electrical charge the application of which enables drawing micro- or nano-fibers from a liquid (polymer solution). Using quasielastic light scattering (QELS) Price et al. (1995) were the first who analyzed the effect of external electric field on the dynamics of polymer chains. Dynamic light scattering (DLS), Wang and Huang (1997), was applied for qualitative comparison when a non-polar polymer (polystyrene) is solved either in polar or non-polar solvent. They revealed that in the latter case the effects from the externally applied electric field were negligible. This motivated Chen et al. (2001) who carried out molecular dynamics simulation to predict the effects of external electric field on the diffusion dynamics of a polar or non-polar chain in polar or non-polar solvents.

Winslow (1947, 1949) started research of rheological behaviour of liquids under an influence of electric field. Especially viscosity η as a main characteristic of so-called electrorheological liquids is intensively studied.

The aim of this contribution is to determine which materials (characterised by structure and dynamics of polymer chains in solution) are suitable for the process of electrospinning if - as a criterion - the rheological behaviour of these materials is taken into account, viz. a course of a curve viscosity ratio η/η_0 vs. electric field strength. The symbols η and η_0 represent the viscosities of a solution in presence and absence of electric field, respectively.

2. Experimental

Polyvinylbuthyral (PVB) that was chosen for this experiment was consecutively dissolved in ethanol, isopropanol and butanol as 10 wt % solution. For viscosity measurements there was

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used an Anton Paar rotational rheometer MCR 501 equipped with an electrorheological cell C-PTD200/E (bob and cup arrangement, diameter 17mm). Surface characteristics of the prepared nanofibre sheets were observed with a scanning electron microscope Vega TS 5130, see Figs.1,2.

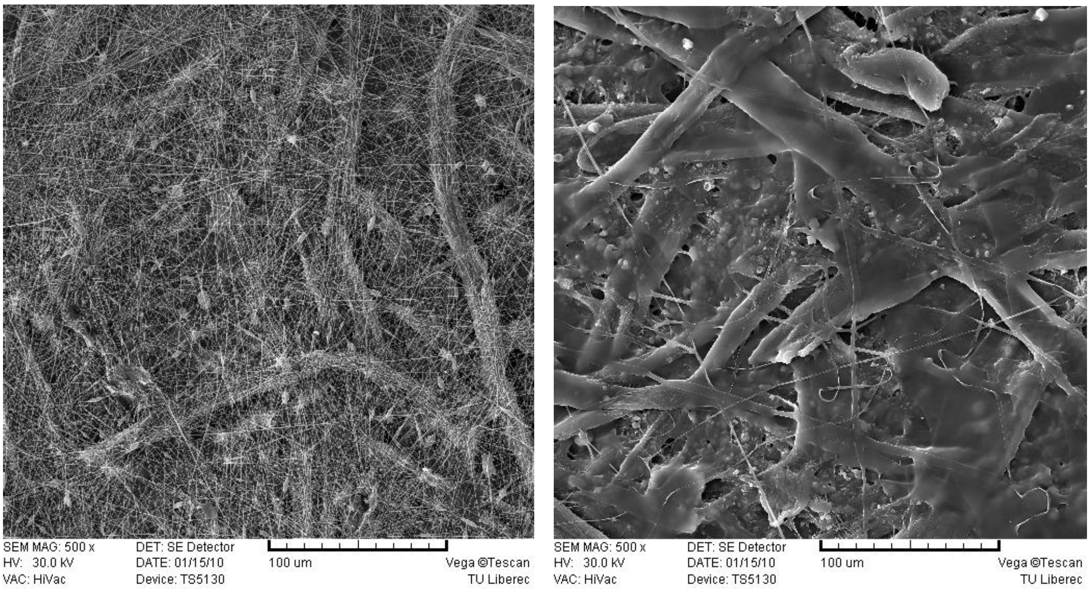

Fig.1 The images of nanofibre sheet from PVB in butanol (left) and isopropanol (right).

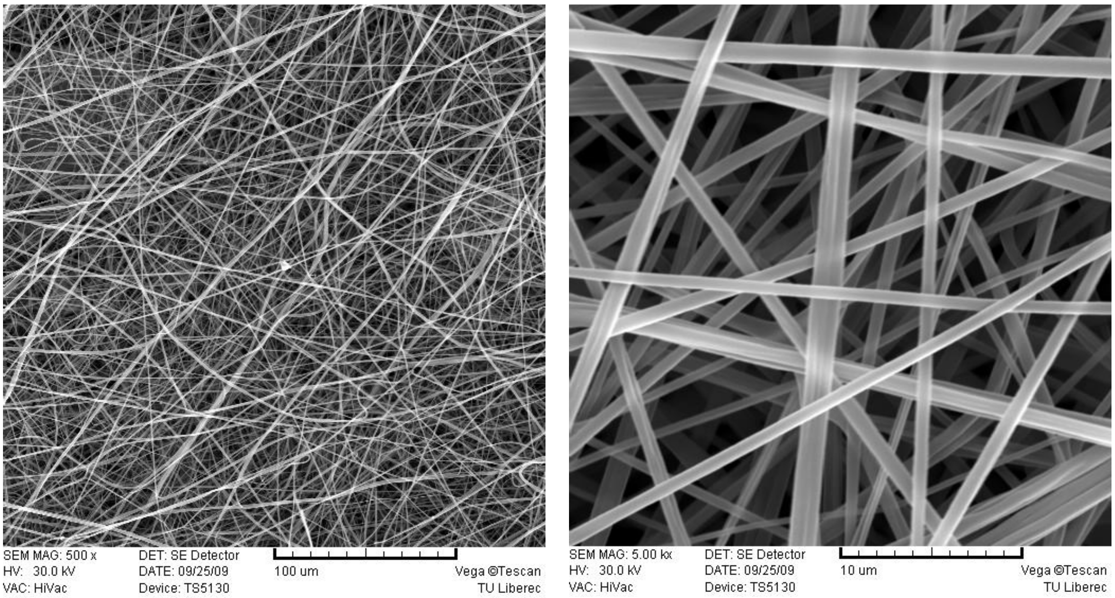

Fig.2 The images of nanofibre sheet from PVB in ethanol.

Whereas the process of electrospinning was carried out in the range up to voltage of 30kV/100mm (=300V/mm), rheological experiments were intentionally measured at comparatively very low values of electric field strength (up to appr. 20V/mm) at 25°C, see Figs.3,4.

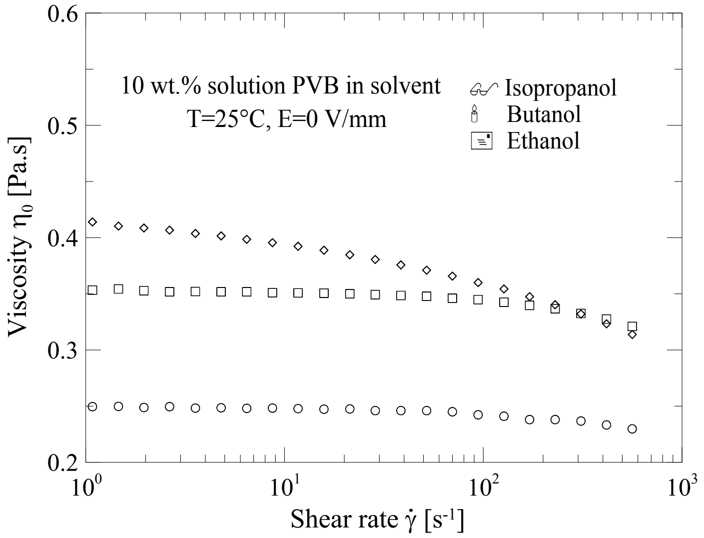

Fig.3 Shear viscosity of PVB solutions (absence of electric field strength).

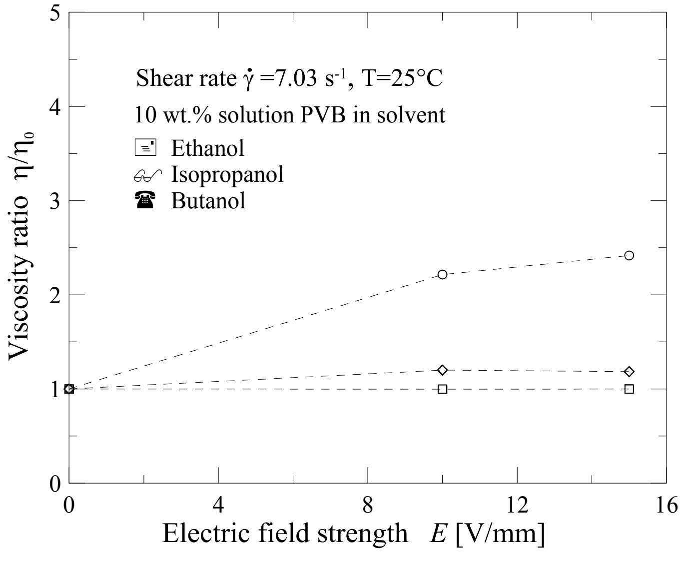

Fig.4 Dependence of viscosity ratio η/η_0 on electric field strength for PVB solutions.

Nevertheless, even in this case it is possible to deduce good or poor electrospinnability of polymer solutions from behaviour of a curve viscosity ratio η/η_0 vs. electric field strength. The more increasing this function the better electrospinnability of the material studied. In this sense ethanol proved to be worse suitable solvent for polyvinylbuthyral (PVB) than the other two solvents: isopropanol and butanol for which their viscosities are affected by electric field strength negligibly. This rheological behaviour has a tight connection with solubility determined through Hansen solubility parameters δ_d (representing energy from dispersion bonds between molecules), δ_p (representing energy from polar bonds between molecules), and δ_p (representing energy from hydrogen bonds between molecules) representing each molecule, see Table 1. These three parameters can be taken as orthogonal coordinates for a point in three dimensional so-called Hansen space. The nearer two molecules are in this space, the more likely they are to dissolve into each other. This is exactly the situation for PVB solved in isopropanol or butanol. Both materials exhibit the nearest location in the Hansen space in comparison with ethanol. This implies the courses of the curves η/η_0 vs. electric field strength for all three cases of the solvents used.

Tab.1 The basic characteristics of the solvents used.

	relative permittivity	boiling point [°C]	δ_d [MPa$^{1/2}$]	δ_p [MPa$^{1/2}$]	δ_h [MPa$^{1/2}$]
ethanol	25	79	15.8	8.8	19.3
isopropanol	20	82	16.0	6.8	17.4
butanol	18	117	16.0	5.7	15.8

3. Conclusion

It was shown that rheological properties of the individual solvents play a dominant role in the process of electrospinning. Structure of nanofibres was documented by the pictures taken with the help of the scanning electron microscope.

4. Acknowledgement

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