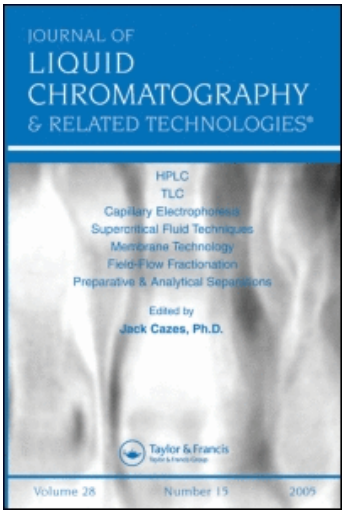

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Planar Electrochromatography in a Closed System under Pressure—Pressurized Planar Electrochromatography

Tadeusz H. Dzido[a]; Paweł W. Płocharz[a]
[a] Department of Physical Chemistry, Chair of Chemistry, Medical University, Lublin, Poland

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Planar Electrochromatography in a Closed System under Pressure—Pressurized Planar Electrochromatography

Tadeusz H. Dzido and Paweł W. Płocharz
Department of Physical Chemistry, Chair of Chemistry, Medical University, Lublin, Poland

Abstract: Pressurized planar electrochromatography (PPEC) is described taking into account last achievements in this mode such as construction of the device and variables influencing on separation efficiency (mobile phase composition, pH of the mobile phase, buffer concentration, applied voltage, chromatographic plate preparation, chromatographic plate type and temperature).

Keywords: Planar electrochromatography, Closed system, Pressurized

INTRODUCTION

Planar electrochromatography is a separation mode in which a mobile phase is driven into movement by electroosmotic effect. Conversely, the mobile phase flow in thin-layer chromatography (TLC) is induced by capillary forces. The high flow rate of the mobile phase and high performance of the separation system are very attractive features of this method.[1–3] Electroosmotically driven linear flow velocity, u_{eo}, of the mobile phase is expressed by the Smoluchowski equation:

$$u_{eo} = \frac{\varepsilon_0 \varepsilon_r \zeta \cdot E}{\eta} \tag{1}$$

where ε_0 is permittivity of vacuum, ε_r is dielectric constant, ζ is electrokinetic (zeta) potential, E is electric field strength, and η is viscosity of the mobile

Address correspondence to Tadeusz H. Dzido, Department of Physical Chemistry, Chair of Chemistry, Medical University of Lublin, Staszica 6, 20-081 Lublin, Poland. E-mail: tadeusz.dzido@am.lublin.pl

phase. As can be seen from the equation above, the electroosmotically induced flow is not dependent on particle diameter, d_p, (in restricted range) of the stationary phase and distance of the mobile phase migration. On the other hand, mobile phase velocity, u_{TLC}, in thin-layer chromatography increases with average particle diameter of the stationary phase and diminishes with migration distance, Z_f, of the mobile phase front according to the equation:

$$u_{TLC} = \frac{\kappa}{2Z_f} \tag{2}$$

where κ is the velocity constant which increases with particle diameter.[4]

In the beginning stage of the development of planar electrochromatography, this method was performed in an open system similar to experiments in conventional planar chromatography.[5–13] The open system means that three phases (gas, liquid and stationary) were involved in the separation process. Abbreviation of planar electrochromatography performed in an open system was called PEC.[1] The separation process with a PEC mode was performed applying chromatographic plates initially dry or prewetted. Two main disadvantages are inherent in this mode. One is concerned with Joule heat release and the second with mobile phase flux to the surface of the adsorbent layer.[11,12] The former effect leads to evaporation of the mobile phase from the separation system leading to poor repeatability of migration distance of solutes to be separated. In some cases, this effect can be advantageous regarding separation performance.[12] The last effect is responsible for considerable broadening of sample zones and poor repeatability of migration distances. This effect was reduced to some extent by application of an appropriate buffer concentration in the mobile phase,[11] or a special strip of counter plate fixed to the adsorbent layer between solvent entry position and start line of the sample.[13] However, these attempts were not satisfactory and reproducibility of retention was still worse than in a TLC mode.

Considerable progress in the development of planar electrochromatography was made when Nurok et al. described a device for planar electrochromatography operated under pressure in a closed system.[14] The prewetted adsorbent layer of the chromatographic plate (with sample mixture on it) in this device was covered with a Tefon foil and ceramic sheet, which were pressed to the adsorbent layer with a hydraulic press. This mode was named by the authors as pressurized planar electrochromatography (PPEC). Influence of vapour phase and flux of solution of the mobile phase to the surface of adsorbent layer on the quality of separation were eliminated. Repeatability of the migration distance of solutes was enhanced using this device in comparison to previous experiments performed in open systems of PEC. Other authors also reported on the construction of devices for PPEC.[15–18]

All types of devices for PPEC possess two main elements: a high voltage power supply and a chamber for PPEC with the chromatographic plate, Figure 1. A high voltage supply is used for generation of an electric field,

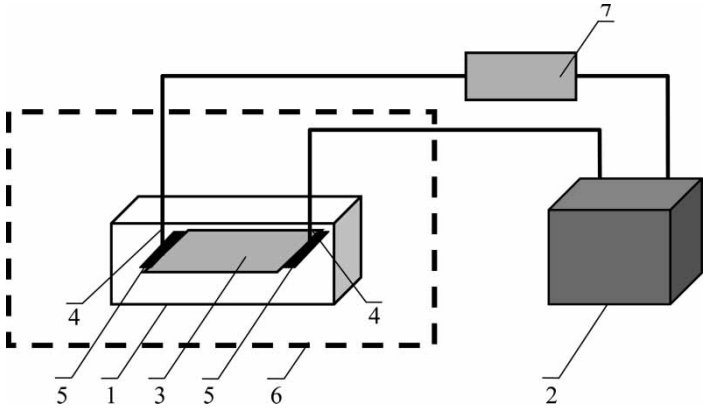

Figure 1. Conceptual view of the device for PPEC; (1) chamber for PPEC, (2) high voltage power supply, (3) chromatographic plate, (4) electrodes, (5) reservoir of the mobile phase, (6) cabinet for PPEC chamber, (7) ammeter.

which is applied for induction of electroosmotic flow through the chromatographic plate. The chromatographic plate is placed in the chamber for planar electrochromatography both in PEC and PPEC modes. The chamber should be inserted in a special cabinet, e.g., made of plexiglass, which protects an operator against a short circuit.

Planar electrochromatography performed under pressure offers important advantages relative to conventional planar chromatography, e.g., higher speed of separation and higher performance of the separation system. These advantages make this method attractive for the separation of sample mixtures of different types. However, development of this method is relatively slow, probably due to technical problems which are difficult to overcome. In this paper, we describe the contemporary status of the PPEC mode and variables which can influence separation efficiency.

DEVICES FOR PPEC

The main differences in construction of the contemporary devices reported in the literature are related to the chamber for planar electrochromatography (the part of the device for PPEC in which the chromatographic plate is placed). In the device presented by Nurok et al. the chromatographic plate is positioned vertically in a special frame between two die metal blocks,[14] (Figure 2) which press the teflon foil and ceramic sheet to the adsorbent layer of the chromatographic plate. The bottom part of the chromatographic plate protrudes from the die blocks. The protruded bottom edge of the chromatographic plate is dipped in the mobile phase solution, which is contained in the reservoir (modified glass pipette) with an electrode (anode). The top part

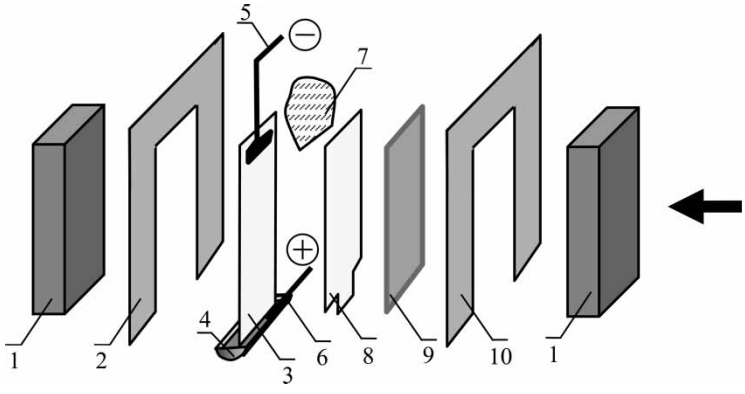

Figure 2. Exploded view of the elements of PPEC chamber proposed by Nurok et al.;[14] (1) metal die block, (2) frame (first part) for the chromatographic plate, (3) chromatographic plate, (4) mobile phase, (5) cathode, (6) anode, (7) paper wick, (8) Teflon foil, (9) ceramic sheet, (10) frame (second part) for the chromatographic plate.[14]

of the adsorbent layer is equipped with a platinum electrode (cathode), which is covered with a filter paper wick pressed to the layer with a strip of rubber placed in the frame. The filter paper wick prevents liquid from accumulating in the top part of the chromatographic plate. The ceramic sheet is applied for Joule heat dissipation. The separation process starts when polarization voltage is applied to the electrodes. In his last publication, Nurok et al. described a modified device for PPEC with die block equipped with an internal channel for circulating the liquid, which was applied for temperature control of the separation system.[19]

Other devices for PPEC were designed by our group.[15,16] Our first construction for PPEC was based on a commercially available horizontal DS chamber for TLC.[15] The next device was a quite new construction which is schematically presented in Figure 3.[16] A prewetted chromatographic plate with the adsorbent layer face down is horizontally positioned in the chamber and is completely covered by a teflon foil and silicon sheet, which are pressed to the adsorbent layer by plastic and metal blocks. Special troughs beneath the adsorbent layer situated on both sides of the chromatographic plate are used for mobile phase delivery to the chromatographic plate. Electrodes, anode on the left side and cathode on the right side of the chromatographic plate in Figure 3, are situated in channels for mobile phase solution and are washed with the mobile phase during the electrochromatography process. More detailed description of the device is presented in the reference [16]. An important feature of the equipment is control of the flow rate of the mobile phase. This feature allows the search for the influence of different parameters of the separation system on mobile phase velocity. This is very important with regard to optimization of efficiency of separation.

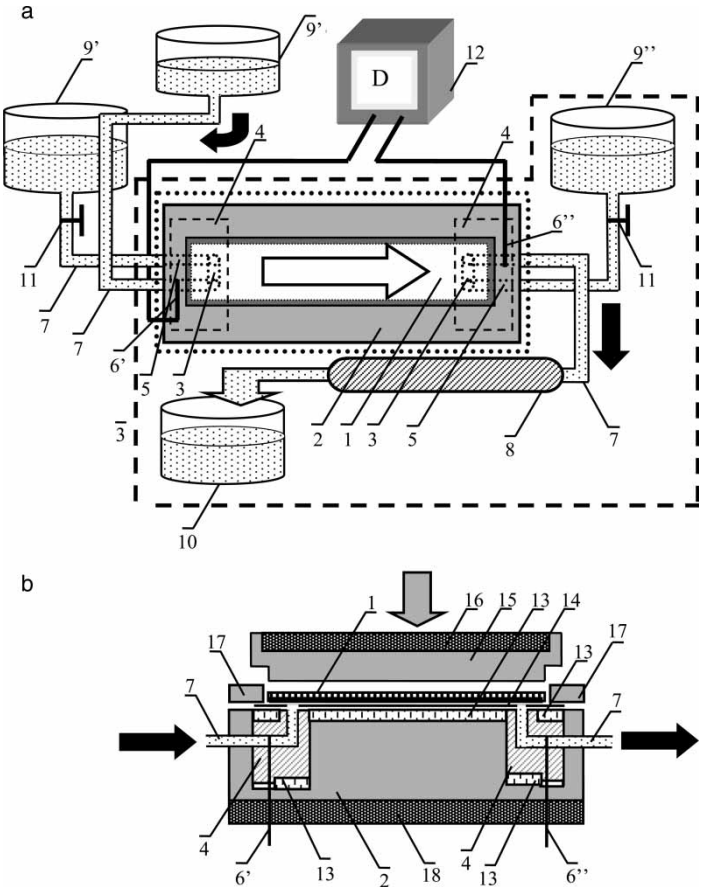

Figure 3. Conceptual view of the device for PPEC;[16] (a) the complete device presented as side view with exception of the elements marked by dotted rectangle as top view, (b) side view of the elements marked by doted rectangle in part (a) of this figure; (1) chromatographic plate, (2) body of the chamber, (3) through, (4) Teflon block, (5) channel for the mobile phase, (6′) anode, (6″) cathode, (7) Teflon tube, (8) 0.1 mL micropipette, (9′, 9″) reservoirs, (10) waste, (11) valve, (12) high-voltage power supply DC, (13) silicon sheet, (14) Tarflen foil, (15) polyacetal base of the lid, (16) steel plate of the lid, (17) frame for chromatographic plate, (18) steel base plate.

Tate and Dorsey presented a device for pressurized planar electrochromatography, which was used for investigation of system equilibration.[17,18] The adsorbent layer was sandwiched between its carrier plate (glass) and cover plastic plate, which was pressed to the adsorbent layer with a hydraulic press.[18] The cover plastic plate was equipped with electrodes to search for

potential drop along the chromatographic plate during the PPEC process. Two mobile phase reservoirs made of teflon were situated on both sides of the chromatographic plate. The chromatographic plate was fed with a mobile phase solution from the anode reservoir through a flat capillary formed by the reservoir wall and strip of glass in a similar way as in the horizontal developing chamber for TLC manufactured by Camag. Collection of the mobile phase solution on the cathode side of the chromatographic plate was similarly performed. The electric field was switched on when the chromatographic plate was completely wetted by capillary action.

VARIABLES INFLUENCING SEPARATION EFFICIENCY

Chromatographic Plate Preparation

In conventional thin-layer chromatography the chromatographic plate is initially dry when the separation process starts. A quite different situation takes place in pressurized planar electrochromatography. In this mode, the chromatographic plate is prewetted when the electric field is turned on to generate electroosmotic flow in the separation system. At the first stage of chromatographic plate preparation its sides have to be sealed with a special sealant. This produces an enclosed area which makes the mobile phase migrates in one direction and prevents the solvent from evaporation. The sample solution can be spotted on the chromatographic plate using, e.g., a microsyringe or automatic applicator. After this procedure, the chromatographic plate is prewetted with the mobile phase solution. In the first experiments of PPEC reported by Nurok et al.[14] the prewetting was performed by dipping the chromatographic plate in the mobile phase solution and leaving a dry space within the sample spot. Then the prewetted chromatographic plate was immediately introduced into the PPEC device to perform planar electrochromatography process. However, the values of migration distances were not of high repeatability. The prewetting procedure was modified by our group. We introduced the procedure of chromatographic plate prewetting followed by sample application.[15] According to this procedure, the chromatographic plate was first prewetted and after that spotted with the sample solution. Then, prewetting of the chromatographic plate could be performed for a desired (longer) time. The prewetted chromatographic plate was covered with a glass plate equipped with a 3 mm diameter hole. Through this hole a sample solution was spotted on the chromatographic plate. As the sample was spotted the chromatographic plate was immediately inserted into the chamber for PPEC. This reversed order of operations (prewetting followed by spotting) is very advantageous for equilibration of the adsorbent layer with solution of the mobile phase and repeatability of migration distance of the sample zones. After prewetting, the remnant of solvent was transferred into an anode reservoir; the chromatographic plate

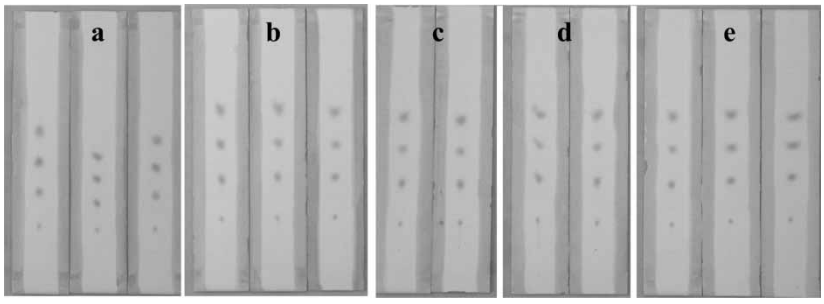

Figure 4. Planar electrochromatograms of test dye mixture; RP 8 TLC plates (Merck), solution of the mobile phase (80% acetonitrile in buffer) in anode reservoir was equilibrated with adsorbent layer for: (a) 3 sec, (b) 1 min, (c) 5 min, (d) 10 min, (e) 30 min.[15]

was prewetted and fed with equilibrated solvent during electrochromatography process. Application of this procedure was reflected by the increase of repeatability of the migration distance of test solutes separated in PPEC systems, Figure 4.[15] As can be seen in Figure 4a, prewetting of the chromatographic plate for 3 sec leads to poor repeatability of migration distance of test solutes. However, increasing prewetting time to 1 min, or longer, substantially increases the repeatability of migration distance. These data were confirmed by Nurok et al.[19] who applied a similar procedure of chromatographic plate preparation to the PPEC process.

Voltage Applied to the Chromatographic Plate

As it can be concluded from Equation (1), the electroosmotic flow is directly proportional to the electric field strength. Several kV was usually applied in PPEC systems to create an electric field in which the electroosmotic flow of solvent was generated. However, the linear relationship between mobile phase flow rate and polarization voltage was observed for a restricted range of voltage applied to polarize the chromatographic plate, Figure 5.[16] It can be seen that for higher values of voltage than 3.5 kV, the flow rate increased more strongly than for lower values. This effect was probably concerned with stronger Joule heat generated during the electrochromatography process, especially when the voltage was higher. Under conditions of higher voltage, a dissipation of Joule heat was not as effective as in lower voltage, which caused a temperature increase in the separating system and is reflected in a decrease of mobile phase viscosity and increase of potential zeta. The pH value and dielectric constant are also dependent on temperature. However, based on the data presented for capillary electrochromatography

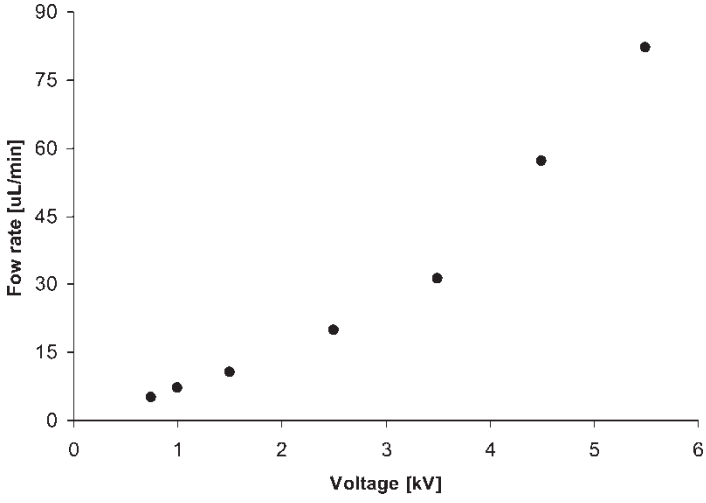

Figure 5. Plot of mobile phase flow rate vs. voltage; 80% acetonitrile in buffer (3.74 mM citric acid, 12.52 mM disodium hydrogen phosphate, pH = 6), TLC RP18 plate (Merck).

systems, the impact of potential zeta increase to raise a mobile phase flow rate seems to be larger than that of viscosity decrease.[20]

Polarization of the chromatographic plate with higher voltage values can be advantageous regarding the increase of throughput of analysis by PPEC. A 1 min,[14] or even shorter,[16] separation time using PPEC was reported in comparison to 24 min separation by conventional planar chromatography, Figure 6.[14]

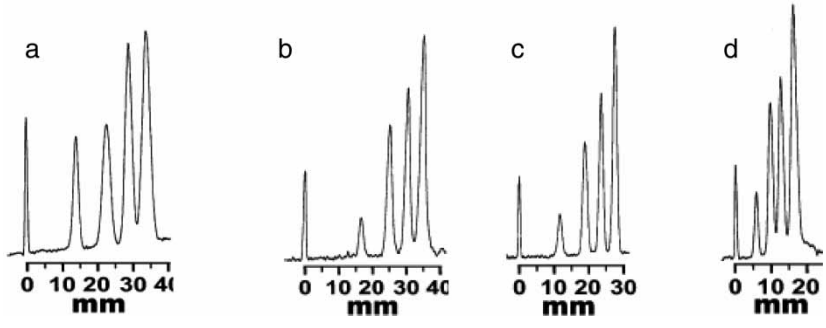

Figure 6. Separation of test mixture by (a) conventional TLC performed in a horizontal DS chamber (Chromdes) using 55% aqueous acetonitrile on LiChrospher RP18 plate (Merck). The separation time was 24 minutes. PPEC separation for 1-min at 9 kV and a pressure of (b) 11.8, (c) 19.7, or (d) 118 atm.[14]

pH Value of Buffer Solution of the Mobile Phase

In the case of silica based stationary phases, which are until now applied in PPEC, silanol group dissociation is responsible for the value of potential zeta in the stationary phase – mobile phase interface. Potential zeta, ζ, can be expressed in terms of superficial charge density, σ, and thickness, δ, of the mobile phase – stationary phase interface according to the equation:

$$\zeta = \frac{\sigma\delta}{\varepsilon_0\varepsilon_r} \tag{3}$$

Dissociation of silanol groups increases when the pH value of the solution rises above the value of 1.5, which leads to increase of the charge density of electrical double layer. This means that the increase of pH value of the mobile phase should enhance electroosmotic flow of the mobile phase. The data presented in Figure 7 confirms this effect.[16] Increasing of pH value of buffer solution in the mobile phase in the range from 2.2 to 6.0 leads to higher values of flow rate of the mobile phase in the system with the stationary phase of the C_{18} type.

It is well known that pH value of the mobile phase leads to retention and selectivity changes in liquid chromatography systems when charged molecules are separated. This effect is also expected to take place in PPEC systems. In addition, selectivity changes in PPEC systems can be diversified relative to liquid chromatography systems, due to participation of the electrophoresis effect on the separation mechanism. So, it should be presumed that the PPEC mode can offer new selectivity of separation of sample mixtures

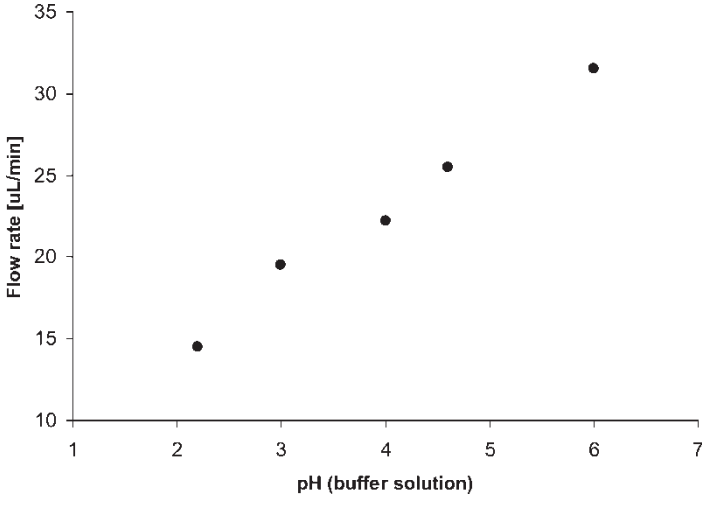

Figure 7. Plot of mobile phase flow rate vs. pH value of buffer solution in the mobile phase. The RP 18 TLC plate (Merck), 80% acetonitrile in buffer, voltage − 2.5 kV.[16]

composed of charged and non-charged molecules of the solutes relative to TLC. There is no data until now which can confirm this assumption for PPEC systems. This effect was confirmed for open systems of planar electrochromatography with the chromatographic plate initially dry.[6]

Buffer Concentration

Buffer solutions applied as components of the mobile phase can determine superficial charge density of the mobile—stationary phase interface by influence on dissociation of silanol groups if silica is applied as base material of the stationary phase (see above). Additionally, buffer concentration influences on thickness of electrical double layer according to the equation:

$$\delta = \sqrt{\frac{\varepsilon_0 \varepsilon_r RT}{2cF^2}} \tag{4}$$

where c is the molar concentration of the buffer salt and F is the Faraday constant. The equation above predicts decrease of electroosmotic flow rate with increase of ionic strength. However, data reported in the literature does not confirm this effect for particulate capillary systems and in PPEC systems, Figure 8.[16] It can be seen in this figure, that the increase of buffer

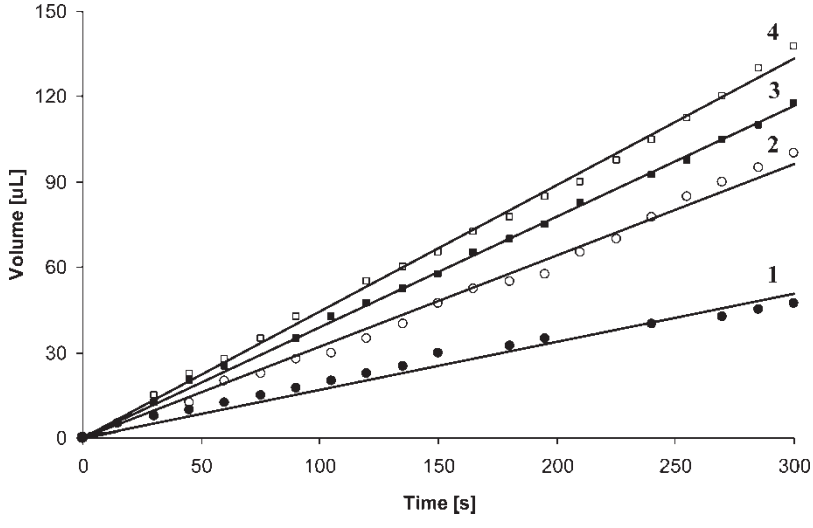

Figure 8. Volume of the mobile phase passed through the chromatographic plate vs. time of experiment; RP 18 TLC plate (Merck), 80% acetonitrile in buffer pH = 4.6 of various concentration: (1) no buffer; (2) 1.34 mM citric acid, 2.32 mM disodium hydrogen phosphate; (3) 5.37 mM citric acid, 9.26 mM disodium hydrogen phosphate; (4) 10.74 mM citric acid, 18.52 mM disodium hydrogen phosphate; voltage −2.5 kV.[16]

concentration in the mobile phase leads to the increase of mobile phase flow rate. Similar conclusions have been drawn from the data presented as migration distance vs. buffer concentration (acetic acid + sodium acetate) from 5 mM to 100 mM.[19] The explanation of the effect lies in diminution of overlapping of the electrical double layer in particulate electrochromatography systems when thickness of this layer is decreased with increase of buffer concentration.

Temperature of PPEC System

Temperature of a liquid chromatography system can considerably influence the retention, separation selectivity of sample mixture, and performance of the separation system. Temperature influences the same properties in pressurized planar electrochromatography systems as in liquid chromatography. However, temperature control in PPEC is more complicated than in liquid chromatography due to Joule heat generation in the separation system. This problem is under control in capillary electrochromatography (CEC)—relatively thick capillary wall leads to effective heat dissipation, so temperature of the capillary electrochromatography system is constant during a run. Conversely, contemporary stationary phases used in PPEC are chromatographic plates commercially available, which are dedicated to TLC with thickness of the adsorbent layer typically in the range 0.2–0.25 mm. This is why Joule heat dissipation during PPEC experiments is not as effective as that in capillary electrochromatography. The only publication in which the authors have presented an attempt to control temperature in a PPEC system was by Nurok et al.[19] They demonstrated that it is possible to control temperature in a PPEC system, and in this way, to influence the separation performance. The highest performance of a PPEC system was obtained at the temperature range 20–30°C.

It was reported that activation temperature of the stationary phase of a C_{18} type show considerable influence on migration distance of test solutes. These data indicate that further application of commercially available chromatographic plates in PPEC will generate some problems with temperature control unless dedicated plates to this method will be offered.

Mobile Phase Composition

Composition of the mobile phase in PPEC systems can influence both retention of the solutes investigated and flow rate of the mobile phase. The first effect has not systematically been investigated till now with the exception of data presented during Planar Chromatography Symposium in Siofok, 2005, Figure 9.[21] We can see in this figure that increase of solvent strength, by increasing acetonitrile concentration in the mobile phase from

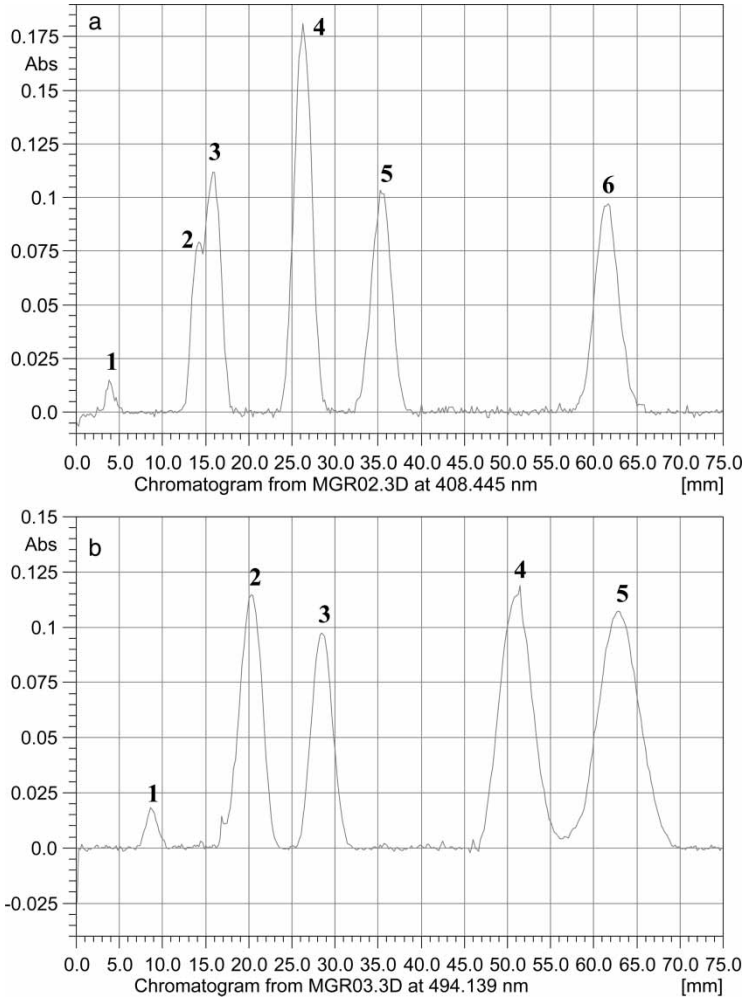

Figure 9. Separation of test mixture by PPEC; 2.5 kV, (a) 80%, (b) 90% ACN, RP-18 TLC plate (Merck), separation time 5 min; (1) Sudan IV, (2) 4-chlorophenylazo-2-naphthol, (3) 1-(3-pyridylazo)-2-naphthol, (4) 4-(diethylamino)azobenzene, (5) 1-(4-hydroxyphenylazo)2-naphthol, (7) 4-nitroaniline; scanned with DAD Scanner (J&M).

80% (Figure 9a) to 90% (Figure 9b) leads to substantial increase of migration distance of the solutes. The peak of 4-nitroaniline is not present on the chromatogram in Figure 9b due to complete elution from the chromatographic plate. Acetonitrile is the most exploited modifier of the mobile phase in capillary electrochromatography and it seems to be the same in PPEC experiments, due to its high value of dielectric constant to viscosity ratio, see Equation (1).

Capillary electrochromatography has been used to investigate retention (as retention factor, k) of neutral molecules dependent on percentage concentration, C, of organic solvent in the mobile phase.[20,22] This dependence of retention is expressed by the equation which was applied for reversed phase liquid chromatography of HPLC and TLC systems:

$$\log k = \log k_w - aC \tag{5}$$

where k_w is retention factor of the solute when pure water is used as the mobile phase and a is constant. We intend to apply this relationship for PPEC systems in the near future.

Type of Stationary Phase

Until now, commercially available plates for TLC with silica based non polar stationary phases have been applied in PPEC.[14–19] There is no systematic investigation of retention and selectivity with regard to these plates in PPEC systems. Otherwise, the influence of stationary phase type on retention and selectivity is well known from many publications relevant to liquid chromatography (TLC and HPLC) and capillary electrochromatography (CEC) separations. Few examples of separation of test mixtures can be cited to demonstrate the quality of resolution and performance of the PPEC systems.[14–16,19] It should be expected, that selectivity of separation in PPEC systems can be considerably changed in comparison to conventional chromatographic systems, due to mixed mechanism of retention in which partitioning of the solute between stationary phase–mobile phase and electrophoresis, when charged molecules are in the mixture, are involved. The next more comprehensive investigation on this subject will certainly be performed when the PPEC mode will be established.

It should be mentioned that quality of the stationary phase seems to be a crucial variable influencing separation efficiency in PPEC systems. This is confirmed by the data which have been reported in the latest publications.[14,16,19] In Figure 10, the plate height vs. mobile phase flow rate is demonstrated for conventional TLC and high performance TLC (HPTLC) plates.[16] The distinguishing feature of these relationships is their different shape. HPTLC plates show a minor increase of plate height with flow rate increase, which is contrary to the relationship presented for conventional plates. Particle distribution is 5–20 μm and 4–8 μm for conventional and high performance plates, respectively. Mean particle size is 10–12 μm and 5–6 μm for TLC and HPTLC plates, respectively. These data indicate that narrower distribution of the particle diameter is responsible for minor loss in performance of the separation system with the increase of flow rate of the mobile phase, which is promising for the high separation efficiency of PPEC system.

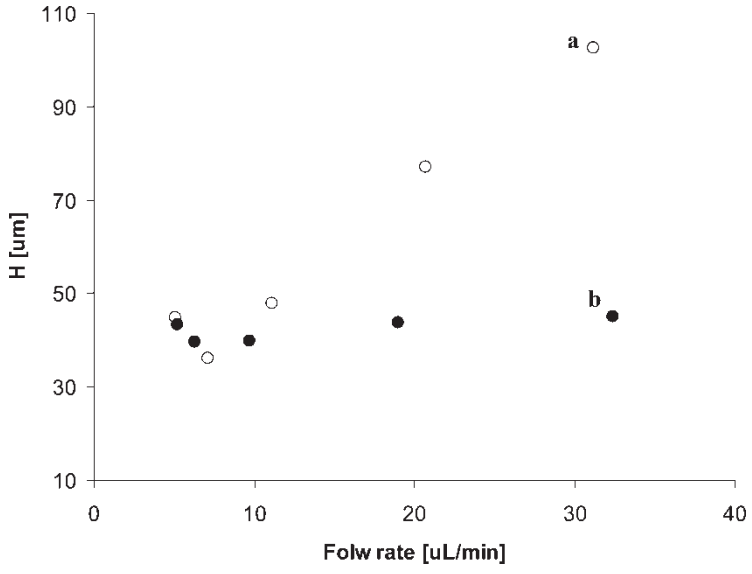

Figure 10. Plate height vs. flow rate of the mobile phase for (a) RP 18 TLC and (b) RP 18 HPTLC plates (Merck). 80% acetonitrile in buffer (3.74 mM citric acid, 12.52 mM disodium hydrogen phosphate, pH = 6), voltage −2.5 kV, test solute-1-(4-hydroxyphenylazo)-2-naphthol.[16]

Nurok et al. have obtained very small values of plate height using LiChrospher plates from Merck.[19] This value is comparable to $2d_p$ (d_p is particle diameter of the stationary phase) and it indicates that the performance of PPEC system is similar to that of HPLC. The values of plate height obtained for capillary systems was reported as equal to particle diameter of the stationary phase applied.[20] However, this very high performance was obtained for uniform particle diameter of the stationary phase. Therefore, it should be expected that the highest performance in a PPEC system can be obtained when similar parameters of the stationary phase will be applied too.

Another variable which is related to stationary phase type is a pressure exerted onto the adsorbent layer of the chromatographic plate. Higher pressure leads to decrease of mobile phase flow rate.[14,19] This effect is more strongly marked for a PPEC system with regular (TLC) plates than with HPTLC plates. This is understandable because regular plates possess the adsorbent layer with a larger distribution of particle diameter than the HPTLC plate does.

Sample Application Mode on the Chromatographic Plate

A microsyringe and disposable capillary pipette have been reported as modes of sample application in PPEC experiments. Sample application

with an automatic aerosol applicator has not been applied until now, due to problems with prewetting the adsorbent layer previously spotted with the sample mixture. On the other hand, spotting the sample solution with an aerosol applicator on a prewetted chromatographic plate leads to evaporation of the mobile phase solution from the prewetted chromatographic plate. A strong stream of gas used for generation of the sample aerosol leads to additional evaporation of solvent from the chromatographic plate.

Total variance, σ^2_{tot}, of the sample zone obtained from the chromatogram after the PPEC experiment is composed of three main elements:

$$\sigma^2_{tot} = \sigma^2_{sa} + \sigma^2_{chr} + \sigma^2_{de} \tag{6}$$

where σ^2_{sa} is variance of sample application on the chromatographic plate, σ^2_{chr} is variance concerned with peak dispersion during migration of sample band through the chromatographic plate, and σ^2_{de} represents a share of detection of the sample zone after separation process to total variance. Variance related to detection of the sample mode seems to be negligible in comparison to variance related to sample migration along stationary phase and sample application, and it can be omitted. It is evident from the experiments performed by Nurok et al.,[19] that diameter of the starting spot is an important parameter influencing final separation. This effect is confirmed by the data presented in Figure 11[19] where plate height is plotted against migration distance of sample zone. As is demonstrated in this figure, the share of variance of sample application to plate height is substantial when

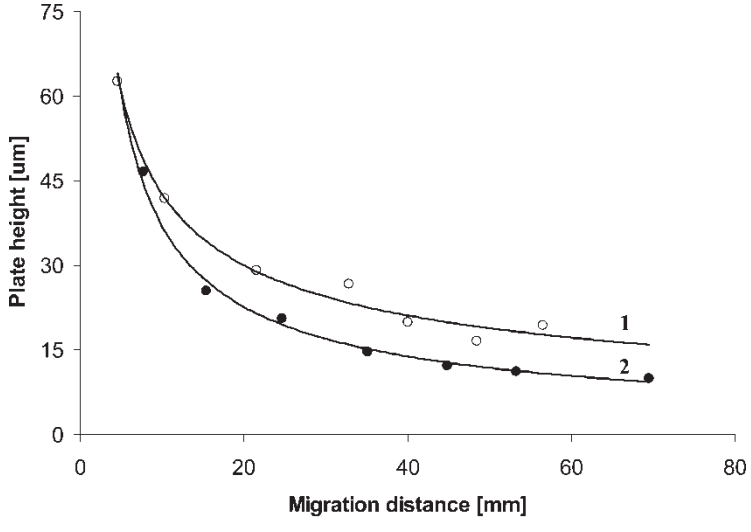

Figure 11. Plate height (H) versus migration distance for test solute. The plot (1) is for the RP 18 TLC and plot (2) is for the RP 18 HPTLC plates (all from Merck).[19]

the sample band migrates a short distance. However, this share diminishes when this distance increases. It has been reported that the average starting spot width measured at its half peak height was equal to 0.52 mm. Reduction of this width, e.g., to the value of 0.2 mm, would lead to the increase of theoretical plate number of about 75 and 38% for migration distances of the sample of 7.6 and 69.3 mm, respectively.[19] However, there is not any available equipment on the market which allows obtaining a starting spot width of such small value.

CONCLUSIONS

The present state of pressurized planar electrochromatography is still far from the situation that one can describe as ready for laboratory application. The main reason for this situation is because construction of the device is not yet fully familiar to an operator. The next reasons are concerned with production of chromatographic plates dedicated to PPEC, chromatographic plate preparation for the electrochromatography process including equilibration of the stationary phase–mobile phase system, and sample application on the chromatographic plate. On the other hand, an electrochromatogram recording can easily be performed with equipment (scanners, densitometers) commercially available for planar electrophoresis and thin-layer chromatography that should facilitate an application of this mode for laboratory practice. However, one can also describe that planar electrochromatography under pressure is far from the beginning stage of PEC development. Examples of separations clearly evidence the advantages of the mode relative to thin-layer chromatography. The main advantages of PPEC are related to higher performance and higher speed of separation. The one disadvantage of PPEC is related to more sophisticated equipment in comparison to TLC. However, this disadvantage can be turned into an advantage if development of this mode will lead to its automation.

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