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ORIGINAL CONTRIBUTION

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Film formation from monodisperse acrylic latices, part 4: the role of coalescing agents in the film formation process

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Abstract The role of coalescing agents in the film formation process is studied by means of the turbidity technique, i.e., analysis of light transmission and interference. The basic influence of coalescing agents is (a) lowering the minimum film formation temperature of the latex dispersion, (b) increasing the drying time and (c) improvement of coalescence. Application of coalescing agents also causes a change in polymer particle size as coalescing agents made of TEXANOL (2,2,4 trimethyl-1,3 pentanediol monoisobutyrate) and ethylene glycol monobutyl ether (EB) were used. Turbidity is shown to be a better method to optimize the amount of coalescing agent in a film formation process than the usual brass bar.

Keywords Film formation · Coalescing agent · Turbidimetry · Light transmission · Interference · Water immersion · Particle size · Particle deformation

Introduction

When a polymer latex is spread over a substrate and allowed to dry, it may or may not coalesce into a continuous film, depending on the temperature. Continuous films are formed above the minimum film formation temperature (MFFT). Powdery conglomerates of little strength are produced below the MFFT. The addition of a small quantity of a coalescing agent lowers down the MFFT, enabling film formation at lower temperatures. Coalescing agents usually are organic liquids with a suitable vapour pressure and solubility in the polymer and water.

The presence of a coalescing agent during the film formation process is as critical as the presence of water. The latex particles have to remain mobile in order to be able to move and pack so that they form a reasonably continuous film. Fast removal of water will not allow this process to occur properly, but will result in the formation of many voids and even may prevent the film formation [1, 2]. During the coalescence process, the coalescing agent does not act to a full extent of volatile plasticizer to facilitate flow and elastic deformation of the polymer particles. The ability of a coalescing agent to plasticize a polymer and its ability to lower the MFFT depends on how closely the solubility parameters of the coalescent and the polymer are matched [3]. The addition of a small quantity of a coalescing agent to a latex dispersion promotes the polymer diffusion across particle boundaries. During the drying process the coalescing agent evaporates from the film, thereby leaving a film with improved mechanical properties [4, 5].

There are some important factors that contribute to the efficiency of a coalescing agent, such as the distribution coefficient, plasticizing capability and the evaporation rate [3, 4].

The distribution coefficient is defined as the ratio of the concentration of the coalescing agent in the aqueous phase to its concentration in the polymer phase. A low distribution coefficient reflects the affinity of a coalescing agent to remain in the polymer phase of the coating. Toussaint and De Wilde [6] have developed a model to predict the distribution coefficient of coalescing agents between latex particles and the aqueous phase in latices.

The second factor, the plasticizing capability of the coalescent, is its capability to lower the MFFT and T_g of a latex polymer [7, 8].

The third factor that contributes to the efficiency of a coalescing agent is its evaporation rate and this depends strongly on the evaporation rate of the pure coalescent and its affinity to the latex [9]. A fast evaporation causes a premature loss of the coalescing agent from the film, whereas too slow evaporation may leave coalescing agent trapped in the latex film, resulting in a non-well dried film.

Apart from these three important factors, the film formation process will also be affected by the drying conditions (temperature and relative humidity). Since the coalescent is an organic compound, humidity will have little effect on its evaporation rate, but at the same time humidity has a strong effect on the evaporation rate of water. The application of a latex paint under high humidity conditions can affect the final properties of the coating dramatically. High humidity retards the evaporation of water. In this case the coalescing agent is the first component to leave the system so that it will not be present anymore when needed at the point of film formation. At low humidity, water is the first component to evaporate and the coalescent concentration will be high at the point of film formation.

If the temperature is lower than the MFFT, proper film formation may not occur. If the temperature is too high, the coalescent may leave the paint formulation too fast, resulting in problems with proper film formation. Therefore, a good film formation will be achieved by proper adjustment of temperature and relative humidity.

The influence of the coalescing agent in the process of film formation can be studied by means of various techniques. Addition of coalescing agent to a latex system causes a marked increase in the polymer diffusion coefficient. By means of the *fluorescent non-radiative energy transfer* technique, developed by Winnik et al. [4, 10–14], the polymer interdiffusion rate was found to increase dramatically by the addition of TEXANOL. In addition to the determination of the diffusion coefficient, Juhue and Lang [15] estimated the penetration depths of the polymer chains in the presence of organic solvents, using the same methods as Winnik et al. They found that the diffusion coefficient decreases with increase of the annealing time. In fact, the diffusion is dominated by short chains at short annealing times and by long chains at long annealing times. An important issue in the latex film formation is to know as to what penetration depth is necessary for the full development of the mechanical strength of a polymer film. The major step to obtain the full strength is the formation of entanglements between the polymer chains that diffuse across the interface. According to polymer diffusion theories, this will be completed during the time needed for the polymer chains to diffuse over a distance of one radius of gyration [16, 17].

Atomic force microscopy (AFM) is another technique for the investigation of the film formation process in neat and coalescing agent–added latex films [18–26]. The measurement of the corrugation height is used as an indicator for the improvement in the film formation process.

The measurement of the latex film *permeability* is a third method to obtain information about the morphological changes in latex films [26–33]. As the application of coalescing agents causes changes in films, the permeability measurement technique can reveal information about the role of the coalescing agent in the film formation process [34].

In the present work, *turbiditmetry* was used (i.e. analysis of light transmission and interference) as a technique to investigate the role of the coalescing agents in the film formation process and their influence on the polymer particle size. In turbidity measurements the progress of the drying process of latices is shown as an increase of the light transmission and, also for monodisperse latices, shown as a shift in the interference minimum ($\lambda_{\min}$) towards smaller wavelengths. By application of more coalescing agents, longer drying times are needed for complete film formation. It is advantageous to optimize the amount of coalescing agent and drying time. In this respect so-called *immersion curves* are measured. These curves are defined as the experimental transmission as a function of water content [26, 35]. The transmission is measured at a wavelength of 600 nm, which is far enough from the interference region.

The immersion curves will be compared with the theoretical transmission curve, as calculated for the Rayleigh-Lorentz model for ellipsoidal inclusions [35, 37–40]. The water uptake is simply measured by gravimetric experiments.

According to Van Tent and Te Nijenhuis [37, 40, 41], the water content in films of monodisperse latices, ϕ_w, can be also estimated from the experimental values of the wavelength at the interference minimum, $\lambda_{\min}$:

$$\varphi_w = 1 - \varphi_p = 1 - \frac{4}{9}\pi\sqrt{3}\frac{r_p n_d}{\lambda_{\min}} = 1 - 2.418\frac{r_p n_d}{\lambda_{\min}}, \qquad (1)$$

where r_p is the radius of the polymer particles, ϕ_p is the volume fraction of polymer in the wet film, and n_d is the average refractive index of the film:

$$n_d = \left(\varphi_p n_p^2 + \varphi_w n_w^2\right)^{1/2}, \qquad (2)$$

Table 1 Some characteristics of latices B6 and S12

Latex	Composition	Solid content	T_g (°C) (DSC)	MFFT (°C) (brass bar)	r_p (nm) (interference)	Refractive index polymer
B6	MMA/BA 60/40 wt%	0.473	35	31	119	1.482
Line missing						

where n_p and n_w are the refractive indices of polymer and water, respectively.

Experimental

In the following experiments the monodisperse latex dispersions S12 and B6 were used (synthesis and characterization are given elsewhere [35, 37, 42]). In Table 1 some characteristics are given. Concerning the particle size, it has to be mentioned that the value for r_p has been determined with the aid of the interference method, because the water volume fraction of the particles during immersion in water was also determined with the aid of the interference method. The past particle sizes were determined with the aid of photo correlation spectroscopy (PCS) and atomic force microscopy (AFM) (see e.g. [35, 42]) and also with the aid of transmission electron microscopy (TEM), scanning electron microscopy (SEM), sedimentation field flow fractionation (SF_3) and quasi elastic light scattering (QELS-Malvern and QELS-Coulter). Our conclusion was that the results yielded by the interference method were in between the results of the other methods (see e.g. [37]). For example, for a particle c10 (see [35]) results for r_p were: QELS-M 157 nm, QELS-C 155 nm, SF_3 138 nm, TEM 125 nm, SEM 139 nm, interference 142 nm; this gives an average of 143 nm with a standard deviation of 11 nm. The fact that the latices in this paper are monodisperse follows from the sharpness of the interference peak (not shown here), because the addition to a monodisperse latex of only 5% of a monodisperse latex with another particle size causes the interference peak almost to disappear (see e.g. [35, 40]), as coalescing agents made of TEXANOL (or TEX) and EB were used (see Table 2).

Before the addition of coalescing agent to a latex dispersion, the pH was adjusted to 9 with the aid of diethanol amine. Under stirring the amount of coalescing agent was added drop by drop to the latex.

Measurement of the MFFT

The EB concentration (based on the latex solid content) in the latex dispersion B6 varied from 0 to 15%. The MFFT of each sample (film with 70 μm thickness) was measured on a brass bar with an established temperature range. The lowest temperature of the transparent crack-free part was chosen as the MFFT.

Drying

The drying processes of both neat and 1% EB-containing latex dispersions B6 and 1% EB-containing were studied via turbidity measurements at 40 °C and 62% relative humidity with the aid of a UV–Vis diode array spectrophotometer (Oriel Instaspec II), enabling the measurement of a complete transmission spectrum from 200 nm to 1,100 nm, as an average of 8 spectra, to be recorded in 0.32 s (for more details see [35, 37]).

Rewetting

The same series of samples as used above in " *Measurements of the MFFT*" were used for the investigation of the rewetting process. The latex films of 70 μm thickness were dried during 1 h at 22 °C and 62% relative humidity. They were cut out in a circular shape with a diameter of 2 cm (i.e. approximately 12 mg) and subsequently submerged in water. The immersion process was followed during 2 –3 weeks and water uptake was measured daily by gravimetry, simply by weighing the samples, every time with a different sample. With the same samples the transmission spectrum was measured immediately after the gravimetric measurement, so that the immersion curve could be constructed by plotting the measured transmission versus the gravimetrically determined water content. For more details the reader is referred to [35].

Influence of type of coalescing agent

For this kind of experiments, latex dispersion S12 and coalescing agent (EB or TEX) containing dispersions (1%) were used. The latex films (70 μm) were dried during 1 h in a conditioning chamber (40 °C and 62% relative humidity). The rewetting processes of latex films were followed during 3–4 weeks.

Particle size

For the determination of the influence of the coalescing agents on the particle size, latex S12 and coalescing agent (EB and TEX) containing dispersions (1%) were used. The particle sizes were measured by drying the latex film completely below the MFFT, but just before the collapse of the protective layer [35, 37, 40, 42]. In this way a powdery film is obtained with a hexagonal closely packed (hcp) structure of particles with a polymer volume fraction of 0.74. The inclusions between the particles are now filled with air. In this state the transmission spectrum is measured; and from the interference minimum, $\lambda_{\min}$, the particle radius r_p is calculated with the aid of Eqs. 1 and 2, where it should be noted that in Eq. (2) we have to change the term $\varphi_w n_w^2$ into $\varphi_a n_a^2 = \varphi_a$, where the index "a" refers to air.

Results

Measurement of the MFFT

Addition of a coalescing agent to a latex lowers its MFFT. This is demonstrated for latex B6 in Fig. 1.

Increase in the amount of the coalescing agent EB leads to a decrease of the MFFT and therefore one can expect that a transparent latex film will be formed easier in the presence of EB. It is well known that the glass transition temperature of polymers is higher in the presence of a small amount of plasticizer, because the first amount of plasticizer is absorbed in the free volume of the polymer, thereby increasing the glass transition temperature. The MFFT will be affected in an analogous way. Hence the dotted line in Fig. 1 at low concentrations (between 0 and 1%) is drawn via a maximum.

Drying

Addition of a coalescing agent to a latex dispersion results in a delay of the film formation. The drying behaviour of latex films (containing neat and coalescing agent) is illustrated in Fig. 2 as interference minimum versus drying time. During the drying process $\lambda_{\min}$ is shifted for both films towards smaller wavelengths. In the EB-containing films the drying process takes not only a longer time but also a slightly larger value of the interference minimum is found at the end of drying process. It seems strange that the presence of only 1% EB has such a big influence on the drying rate of a latex film: from Fig. 2 it appears that the drying time increases approximately from 450 s to 850 s, whereas the amount of EB present after drying has not changed ($\lambda_{\min}$ is slightly higher than that of the latex film dried in the absence of EB). It is improbable that the rate of evaporation of water is influenced by such a small amount of EB.

Table 2 Applied coalescing agents

TEXANOL = 2,2,4 trimethyl-1,3 pentanediol monoisobutyrate $= CH_3–CH(CH_3)–CO–O–CH_2–C(CH_3)_2–CH(OH)–CH(CH_3)–CH_3$ Boiling point 244 °C; relatively hydrophobic coalescing agent $n_D \approx 1.42$
EB = ethylene glycol monobutyl ether = $HO–CH_2–CH_2–O–C_4H_9$ Boiling point 177 °C; relatively hydrophilic coalescing agent $n_D = 1.4198$

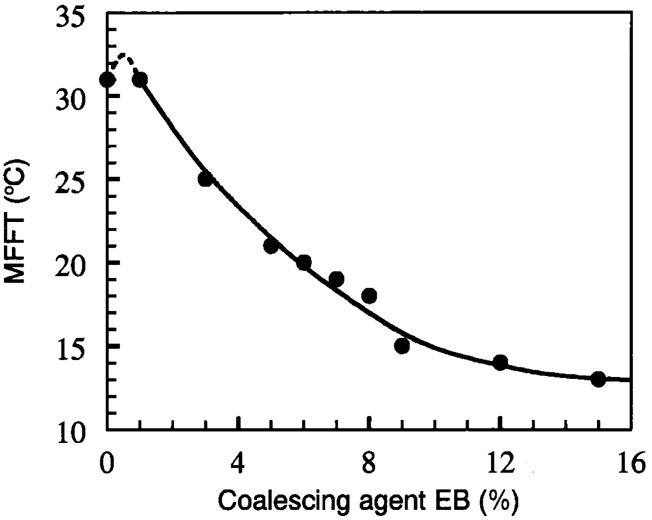

Fig. 1 Influence of the coalescing agent EB on the MFFT of latex B6 films

An explanation of this problem is proposed by Vink. He suggested that EB is almost equally distributed over the water phase and the polymeric phase. From thermodynamic calculations it becomes clear that the evaporation rate of EB/water mixtures is much faster than that of pure water, despite the high boiling point of EB. Moreover, there is strong evidence that EB is not homogeneously distributed over the acrylic polymer particles, but that EB is preferentially present in the outer shell of the particles. As a result, it seems that EB expels the anionic surfactants from the latex particle surface. Hence, in this vision the longer drying time is not explained by increasing amounts of EB, but of increasing amounts of anionic surfactants in the water phase.

Rewetting of EB-containing latex B6 films

The influence of a coalescing agent on the film formation is also revealed in the turbidity of rewetted films. Regenerated interference minima after 400 h of water immersion were measured for EB-containing samples as a

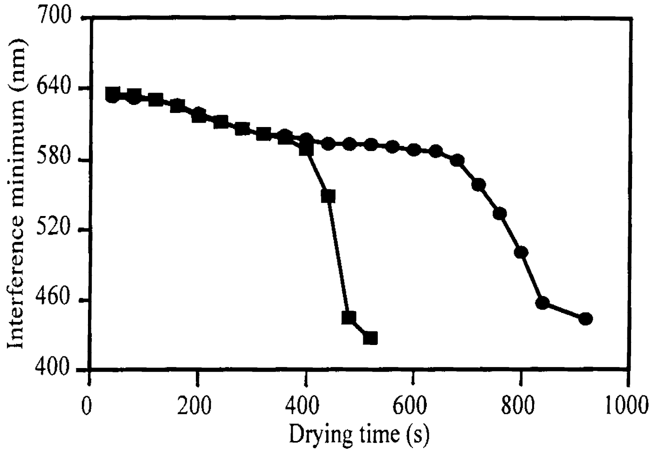

Fig. 2 Influence of coalescing agent on the interference minimum and drying time of drying B6 films. Drying temperature is 40 °C. (*filled square*) neat films, (*filled circle*) 1% EB-containing films

function of EB concentration, shown in Fig. 3. This figure demonstrates the prominent effect of the amount of EB on the regenerated interference minimum of the rewetted latex films. At low EB concentrations (0 to 7%), a somewhat better film formation is observed upon increasing the amount of EB, however, lots of cracks are present in these films. Addition of more coalescing agent leads to the formation of continuous films. This can be seen in Fig. 3 as a sudden decrease in λ_{min}. Further addition of EB causes a small increase in λ_{min} probably for the same reason as in Fig. 2, viz., a residue of the coalescing agent staying in the film after the drying time of only 1 h.

Type of coalescing agent

Particle size

The wave lengths of the interference minima, λ_{min}, of neat latices and of those containing 1% of EB or TEX, measured after drying below the MFFT, just before the collapse of the protective layer, are 580, 566 and 602 nm, respectively. Substitution in Eqs. 1 and 2 results in particle radii of 129, 126 and 134 nm, respectively. Hence the presence of EB causes a decrease of the particle radius and the presence of TEX size to an increase of the particle radius. A possible presence of coalescence agent in the particles itself has only a minor influence on the calculated particles size, because the refraction indices of both coalescing agents are close to that of the polymer (i.e. 1.42 vs. 1.485).

Immersion patterns of 1% EB or TEX containing S12 films

The immersion patterns of neat films and films containing 1% of EB and TEX, dried for 1 h at 40 °C, are shown in Fig. 4. As mentioned earlier, the water volume fraction of the dried films after immersion in water was determined gravimetrically as water uptake. There is no agreement at all with the Rayleigh-Lorentz model: the experimental transmission is much lower than the prediction of the model . However, in part 2 of this series of papers [26], it was shown that there might be several pitfalls in the determination of the water content in dried and in water immersed films. One of them, the *second pitfall*, is the presence of water in non-well dried films. By taking into consideration of the fact that a certain amount of water is still present in the dried films before submersion in water (with remaining water content ϕ_{wr}), the water content during immersion can be corrected. In this way it is possible to find this amount of remaining water in a trial and error calculation in order to get the best fit with the theoretical immersion curve. For the three films the volume fractions of water still present before immersion were found to be $\phi_{wr} = 0.029$, 0.044 and 0.042 for neat films, 1% EB-containing films and 1% TEX-containing films, respectively. In Fig. 5 the measured relative transmission is plotted versus the corrected water volume fraction and it now shows a fair agreement with the theoretical curve. However, it is worth mentioning here that in the Rayleigh-Lorentz model, the transmission is dependent on the radius of the polymer particles. Although the particle diameters of the three latices are different, we nevertheless show only one full line for model calculations, because in the considered transmission region the particle size (in the range from $r_p = 126$ to 134 nm) dependence is only small.

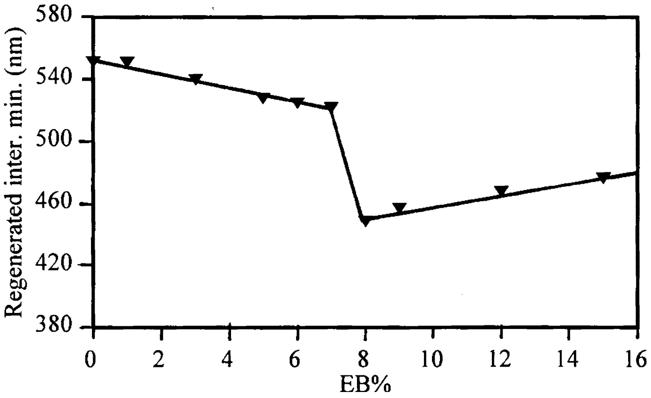

Fig. 3 Influence of the coalescing agent EB on the regenerated interference minimum during water immersion of latex B6 films, that were previously dried at 22 °C during 1 h

The particle radii in the various latices, the regenerated interference minima measured after 400 h of immersion and the water volume fractions calculated from λ_{min} with the aid of Eqs. 1 and 2, are reported in Table 3. Although again the differences are small, the EB-containing films show smaller values for λ_{min} than

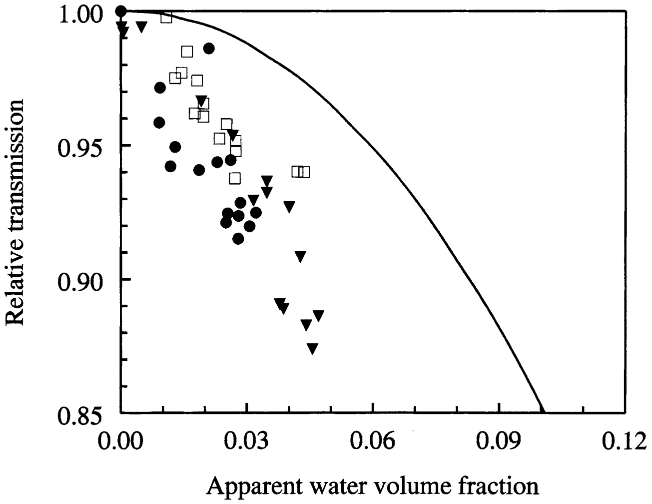

Fig. 4 Immersion patterns of latex S12 films with and without coalescing agent that were dried during1 h at 40 °C. (*open square*) neat films; (*filled circle*) 1% EB-containing films; (*filled inverted triangle*) 1% TEX-containing films; full-line Rayleigh–Lorentz model for ellipsoidal inclusions [35, 37–41]

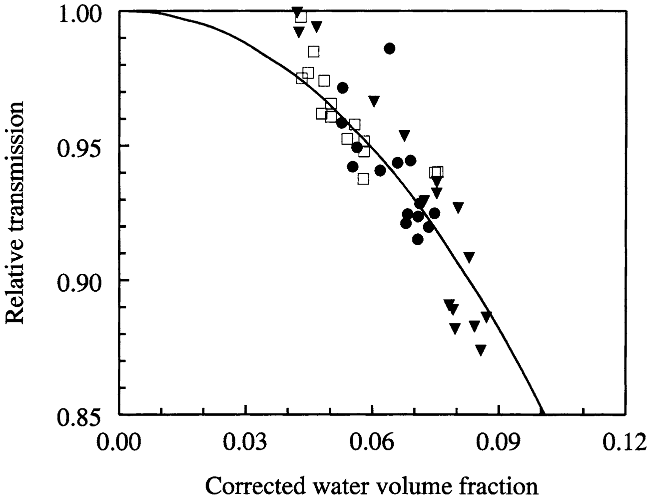

Fig. 5 Immersion patterns of latex S12 films of Fig.4, but now corrected for remaining fraction of water, ϕ_{wr}, after drying. (*open square*) neat films; (*filled circle*) 1% EB-containing films; (*filled inverted triangle*) 1% TEX-containing films; full-line Rayleigh-Lorentz model for ellipsoidal inclusions [35, 37–41]

that of the neat and TEX-containing films. The corrected gravimetrically determined amounts of water absorbed after 400 h of immersion in water (the corresponding largest values in Fig. 5), are also reported in Table 3. They are not in agreement with those calculated from λ_{min}. However, in the calculation of the water volume fraction, the particle sizes calculated from λ_{min} as measured in the dried state has been used, just before the collapse of the protective layer. In part 2 of this series of papers [26], it has been reported that the films of neat latices that were dried during 1 h at 40 °C, still absorb water in the particles themselves during the immersion process. This resulted in an increase of the particle radius from 129 nm to 131.5 nm. Hence the particle radii of the various latices are now corrected by substituting in Eqs. 1 and 2 the corrected water volume fractions as obtained by gravimetry. Results, varying from 131.1 nm to 131.5 nm, are also reported in Table 3. It follows that the particle radii agree mutually very well and that they also agree very well with the mentioned results of 131.5 nm, obtained in part 2 of this series of papers [26]. Water seems to be absorbed again in the polymer particles to an amount independent of the original presence of the coalescing agents. Apparently, the coalescing agents have been more or less completely leaked out from the latex particles during the immersion process, and thus have no influence anymore on the particle sizes.

Table 3 Particle radius (r_p), wavelength of regenerated interference minimum ($\lambda_{min,reg}$) and water volume fractions of latex films (ϕ_{w1}, calculated from λ_{min} and ϕ_{w2}, obtained from Fig. 5) that were dried during 1 h at 40 °C, and subsequently immersed in water during 400 h

Latex	Neat	EB-containing (1%)	TEX-containing (1%)
r_p (nm)	129	126	134
$\lambda_{min,reg}$ (nm)	507	505	512
ϕ_{w1} from λ_{min}	0.095	0.114	0.066
ϕ_{w2} from Fig. 5	0.075	0.075	0.087
r_p corrected (nm)	131.5	131.1	131.3

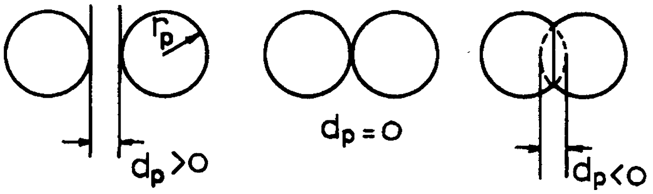

Fig. 6 Schematic representation of interparticle distance d_p: before coalescence ($d_p > 0$), at the point of coalescence ($d_p = 0$) and during deformation ($d_p < 0$)

A comparison between the extents of film formation in latex films with different particle sizes can also be made by determination of the indentation during particle deformation (Fig. 6). The degree of the indentation ($-\,e_p/r_p$, where e_p is half the interparticle distance = 1/2 d_p and r_p is the particle radius) in bi-axial particle deformation in a hcp structure, is given by [37]:

$$-\frac{e_p}{r_p} = 1 - \sqrt{\frac{\pi^2}{27\varphi_p^2} + \frac{1}{3}}, \tag{3}$$

where ϕ_p is the polymer volume fraction.

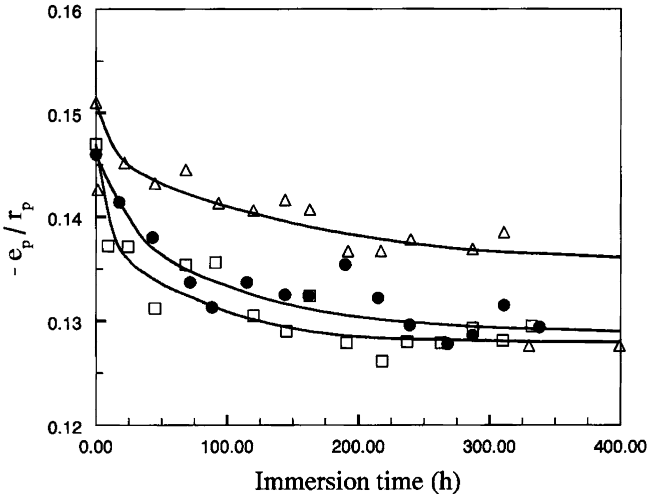

Fig. 7 Influence of coalescing agents on the indentation during water immersion of latex S12 films that were dried during 1 h at 40 °C. (*open triangle*) neat films; (*filled circle*) 1% EB-containing films, (*open square*) 1% TEX-containing films. Lines are drawn to guide the eyes

As shown earlier, the amount of remained water in neat and in 1% EB- or TEX-containing latex films is $\phi_{wr} = 0.029$, $\phi_{wr} = 0.044$ and $\phi_{wr} = 0.042$ after 1 h drying, respectively. Therefore, for the neat films $\phi_p = 0.971$ and $-e_p/r_p = 0.151$, for EB-containing films $\phi_p = 0.956$ and $-e_p/r_p = 0.144$ and for the TEX-containing films $\phi_p = 0.958$ and $-e_p/r_p = 0.145$. Starting with this information and assuming the particle interstices to swell, Eq. 3 can be used to follow the particle deformation. For complete indentation (i.e. $\phi_p = 1$) it follows $-e_p/r_p = 0.164$. The results are shown in Fig. 7, where it appears that the extent of particle deformation during previous drying decreases in the range TEX containing, EB containing and neat films, and this would mean that the best film obtained after drying during 1 h at 40 °C is the neat film, followed by the 1% EB-containing film, that is only a small fraction better than the 1% TEX-containing film. This does not mean, however, that the neat film will be the best one under all circumstances: the best film obtained will depend on time, because coalescing agent containing films need longer times to dry completely.

Discussion

By drying a latex film above its MFFT, a continuous film is formed. In order to dry a film properly at lower temperature, addition of a coalescing agent is necessary. This amount can be estimated via the classical method using a brass bar or via turbidity measurements. The necessary amount of EB is 6% as revealed by the classical method, as demonstrated in Fig. 1. This amount lowers the MFFT to 20 °C, which is lower than our drying temperature of 22 °C. Although the formation of a crack-free film is expected, in practice lots of cracks were present in those latex films and it can be concluded that only the brass bar method gives a rough estimation of MFFT and of the amount of coalescing agent to be added. Turbidimetry is a much more accurate method for the estimation of the MFFT [37]. The amount of coalescing agent can be optimized, as is demonstrated in Fig. 3. Our results show that addition of 8% EB not only gives the lowest regenerated interference minimum (λ_{min}) after 1 h of drying, but also results in the formation of a crack-free, continuous film. At this amount of 8%, the MFFT of the latex film is lowered to 17 °C, which is well below the drying temperature of 22 °C (see Fig. 1). Therefore, the lowest value of λ_{min} corresponds to the most effective amount of the coalescing agent (see Fig. 3). In part 5 of this series of papers [44], it will be shown that ageing of these films has an important effect on the film properties: first, the sudden drop in λ_{min} is larger when the amount of coalescing agent is larger; second, the eventually obtained value of λ_{min} decreases with increasing amounts of coalescing agent (up to 15%), which means that the eventually obtained films are better when the amount of coalescing agent is higher. It has to be emphasized, however, that this takes almost one year of ageing at room temperature.

Coalescing agents also cause changes in polymer particle size. EB, after dissolving in the water phase, replaces the surfactant layer, which causes shrinkage of the particles. TEX replaces the surfactant molecules or absorbs in the outer layers of polymer particles. TEX molecules are comparable in size with surfactant molecules. It has also places for water absorption. Therefore, after its adsorption on the polymer particle the effective particle sizes will be larger. The wavelength of the regenerated interference minimum (λ_{min}) and the particle deformation are directly linked to the polymer particle size. In literature the connection between the particle deformation and particle size is related to the MFFT, which is lower for smaller particles [37–43, 45, 46]. The size of the remaining interstices between the polymer particles after film formation depends on the size of the polymer particles and the extent of the particle deformation. For the same level of transparency, bigger particles need to be deformed more than the smaller ones. Hence, smaller particles yield more transparent films than bigger particles [37, 40, 41]. The same results (however, a smaller range of the regenerated interference minimum and a higher degree level of the transmission vs. wavelength) are observed for EB-containing films in comparison with TEX-containing films.

In part 5 of this series of papers [44], the effect of the coalescing agents EB and TEX is studied more into detail.

Conclusions

Coalescing agents are, among other additives, necessary for film formation of latices with higher glass transition temperatures. They lower the MFFT of the latex dispersion, retard the film formation process and have an influence on the polymer particle size. On the basis of the nature of the coalescing agent, the polymer particle size can decrease or increase.

The immersion behaviour of neat films lies in between EB- and TEX-containing films. TEX-containing latex films show a higher tendency to particle redispersion after 1 h of drying. This is attributed to the influence of TEX on particle size and the rate of the film formation process, which becomes slower. In a forthcoming paper we will report our studies on the influence of drying temperature, ageing time and ageing temperature on the film formation of coalescing agent containing latex films.

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