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Water-based nail polish innovation

Nail polish has become a true fashion accessory and to some degree an art form. It is a beauty product that attracts consumers with very affordable prices even in rough economic times. In the last few years, beauty services have been challenged by at-home alternatives. For example, many consumers have opted to adorn their nails at home instead of getting them done in a professional nail salon. As a result, nail polish has been among the fastest growing categories in global colour cosmetics sales and has registered more than 7% growth in 2010, according to Euromonitor international.

Thanks to a wide array of novel colorants and pigments, manufacturers can quickly evolve and expand their nail colour palettes to follow the most current fashion trends as well as create new ones. Colour trends are very different depending on country or cultures. However the buying criteria remain the same for all consumers: ease of application, quick drying, gloss, density of the colour and, of course, durability.

ABSTRACT

Syntran PC5620 is an aqueous acrylic polymer dispersion specifically designed for the formulation of water-based nail polishes. When properly formulated this polymer exhibits very interesting properties such as quick dry time, high gloss, excellent adhesion, durability and wear properties. These properties are crucial in developing an effective 'water-based' nail polish able to compete against commercially acceptable 'solvent-based' nail polishes.

Properties and composition of standard nail polish

A nail polish is defined as a pigmented coating applied to human fingernails or toenails to decorate and/or protect the nail plate. A cosmetically acceptable nail polish should have the following properties:

- Good levelling for an easy application.
- Good adhesion in order to provide long lasting results.
- Quick drying or film formation.
- Bright and vivid colour.
- High gloss.
- High coverage.
- Homogeneity throughout film.
- Sufficient elasticity to be able to follow the nails' curves without cracking.
- Suitable hardness to resista shock and minimise chipping.

Other crucial qualities include:

- Good water resistance: women want to be able to wash their hands several times without reapplying their polish.
- Stability of the formulation: a too quick or too high sedimentation of the product could be prejudicial for the success of a product.
- The end product should be safe and innocuous for the consumer.
- Nails should recover their original appearance after removing the polish without staining nail plate.

As in all categories of cosmetic products there is no single formula for nail polish. Nevertheless, the nail care market is dominated by the so-called 'solvent-based' nail polish (non-aqueous). The majority of these products are based on typical components including: film-forming agents, resins, plasticisers, solvents, pigments and thixotropic agents. The exact formulation of a nail polish depends on choices made by formulators in the research and development phase. The key ingredient of a nail polish is the film-forming agent. The main film-forming agent used today in 'solvent-based' nail polish is nitrocellulose.

Nitrocellulose provides mechanical and chemical resistance to the nail polish, however, a nitrocellulose film alone is too brittle and has poor adhesion to the nail surface. A resin is typically combined with nitrocellulose to provide adherence at the surface of the nail. Plasticisers are also added to the formulation to give elasticity and flexibility to the film. These chemicals

embed themselves between polymer chains, spacing them to make the film sufficiently flexible in order to avoid cracking or chipping after drying. Dibutylphtalate (DBP) was extensively used as a common plasticiser in nail polish formulations for many decades before recently being banned. Besides nitrocellulose, resins and plasticisers, solvents such as butyl acetate and ethyl acetate are integrated into the formulation to dissolve or create a medium for the formulation and to help the dispersion of nitrocellulose and resins. When applied as a thin coating, these solvents will evaporate quickly to leave behind the pigmented or coloured film. Pigment or effect particles in the nail polish typically need to be suspended, in order to create 'quasi-stable' formulations. With this goal in mind, thixotropic agents like bentonite or silica are added to the formulation. The purpose of these ingredients is to suspend or stabilise the pigments in the formulation, which slows down particle sedimentation in the container and allows shear thinning of the formulation during the application phase for a better levelling.

Pigmented nail polish represents about 75% of global nail polish market. Choice of pigment or effect particles and their ability to mix well with the solvents and other ingredients is essential to produce a good quality product. Most often, inorganic pigments like titanium dioxide or iron oxides are used to provide an opaque and vivid colour on the surface of the nails. Different effects, like pearly or sparkling effects, can be added by the use of raw materials like mica and bismuth oxychloride. The trend is now to create more artistic or dramatic effects such as metallic shades, crackled look and even animal patterns.

New trend

As already mentioned, solvent-based products containing nitrocellulose dominate the nail polish market today. However these products are facing increased scrutiny because of the solvents they contain and their potential toxicity. Furthermore, the manufacturing of solvent-based nail polish requires special facilities designed to control the hazards of fire and explosion, which is an additional issue for cosmetic producers as well as shipping restrictions. Nail polish manufacturers are slowly shifting toward less toxic formulations, as consumers become conscious of the potential health and environmental impact of these conventional solvent-based nail polishes. The trend for 'without' or 'free of' has also hit the nail polish industry and it is now possible to find water-based nail polishes

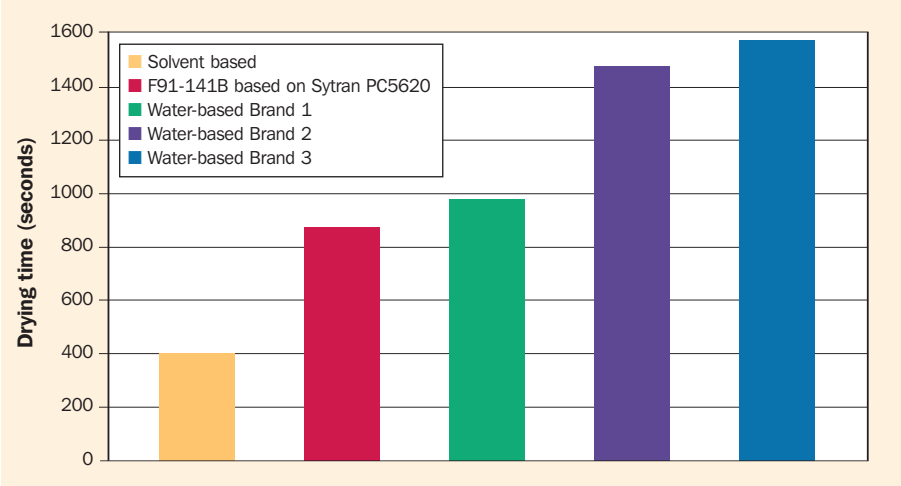

Figure 1: *Drying time evaluation – ASTM D5895-03.*

on the market. This new category of nail polish offers a safe and environmentally friendly alternative to the current solvent-based formulations. However, many of the currently available water-based nail polishes are targeted at young girls because of poor performance characteristics.

Therefore Interpolymer has developed a new acrylic polymer dispersion specifically designed to formulate water-based nail polishes. This technology platform was given the acronym SAFE – which means State-of-the-art Acrylate Film-forming Emulsion.

This new acrylic polymer dispersion exhibits excellent initial gloss and gloss retention. The dry-to-touch time is very fast compared to other existing water-based nail polishes. It exhibits excellent water and wear resistance, hardness and adhesion to the nail surface. The SAFE technology eliminates all those concerns with regard to safety hazards, toxicity and VOC issues currently facing solvent-based nail polishes. Moreover the use of this technology allows a safe production process without the use of specialised facilities.

Formulations

Clear nail polish formulations were developed with the new acrylic polymer dispersion. Thanks to their aqueous composition these formulations are compatible with other water-based actives and can be promoted in the nail care treatment segment. Marketing claims like hardening, hydration, health, protection could be easily obtained with the addition of water-based actives.

The compositions of four clear nail polish formulations are given in Formulation 1. The basic components of these water-based nail polishes are the same as that of solvent-based formulation. They contain a solvent (water), a film-forming agent and plasticisers. The film-forming agent is the new acrylic polymer dispersion. The polymer dispersion on its own does not form a film but a crystalline powder on drying. Therefore plasticisers are present in the formulation to reduce the Minimum Film Formation Temperature (MFFT) of the final formulation, permitting it to be transformed into a clear, durable film when allowed to dry at room temperature.

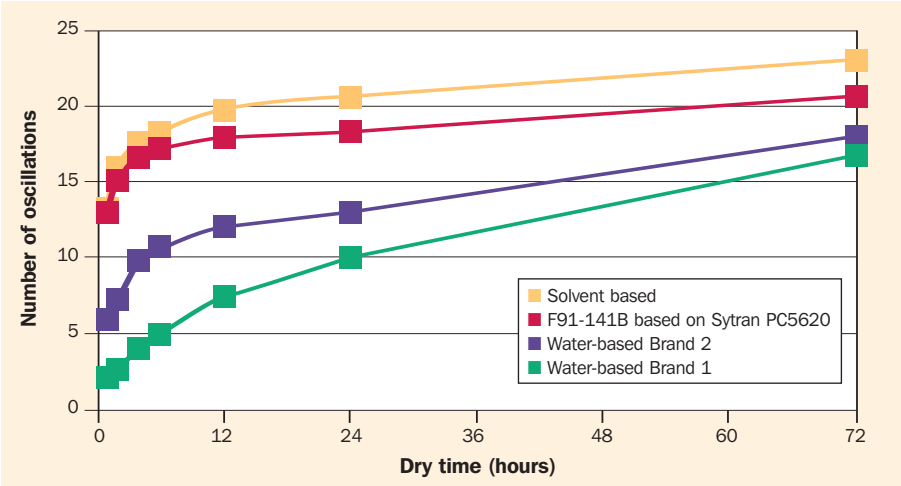

Figure 2: *Film hardness evaluation with time.*

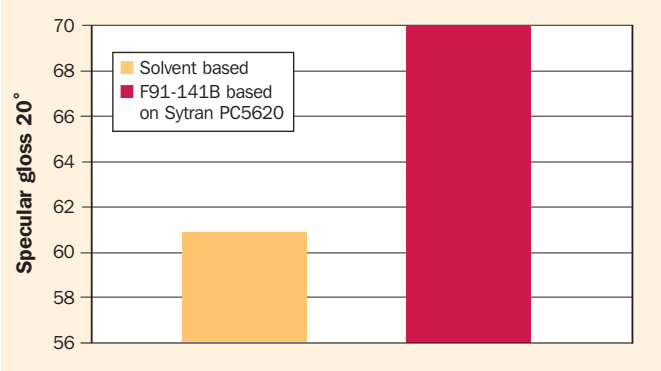

Figure 3: *Gloss measurement.*

Two types of plasticisers are used – permanent and fugitive (also referred to as coalescents). Permanent plasticisers are absorbed completely by the polymer upon drying and remain in the film to provide continuing plasticisation. Coalescents, which volatilise during drying process, are used to temporarily lower the MFFT of a nail polish during the drying phase. Therefore the amount and types of the various plasticisers required to produce an optimised nail polish film are of critical importance.

Testing and results

The formulation F-91-141B was evaluated against commercially available water-based and solvent-based nail polishes.

Drying time

One of the main demands of consumers concerning nail enamels is a quick drying time. A trend in the cosmetic industry today is that consumers are looking for more convenient products which apply quickly and easily, and save them precious time. The drying time of a nail polish formulation containing 92% of the new acrylic polymer dispersion was evaluated against three water-based and one solvent-based competitor currently on the market. For this test a film with a thickness of 150 µm was applied on glass under controlled humidity (55% RH) and temperature (21˚C) and the drying time of the film was evaluated with a standardised method (ASTM D5895-03).

This test allows one to determine the rate of dry film-formation of organic coatings using a straight line mechanical drying time recording device. In this test method, a rod with a hemispherical tip, fitted to a carriage, is brought into contact with the fresh film at one end of the test strip and moved lengthwise at a selected constant speed. The drying time is calculated from the distance travelled, measured using a graduated rule along the edge, corresponding to the various stages observed on the trace.

Among all the water-based products, the formulation containing 92% of the

Formulation 1: Water-based acrylic nail polishes.					
		%W/W			
	INCI designation	F-91-141B	F-92-011B	F-92-001D	F-92-016B
Phase A					
Syntran PC5620[3]	Styrene/Acrylates/Ammonium Methacrylate Copolymer	92.000	92.500	92.250	94.500
Phase B					
Benzoflex 9-88[1]	Dipropylene Glycol Dibenzoate	2.400			
Dowanol DPM[2]	Dipropylene Glycol Methyl Ether		3.750	2.325	
Dowanol PnB[2]	Propylene glycol *N*-butyl Ether	4.400	2.625	3.333	
Butylene glycol	Butylene Glycol			0.930	
Dowanol TPM[2]	Tripropylene Glycol Methyl Ether				2.750
Dowanol DPnP	Dipropylene Glycol *N*-propyl Ether				1.925
Syntran KL219-CG[3]	Ammonium Acrylates Copolymer	1.200	1.125	1.162	0.825
Total		100.00	100.00	100.00	100.00
Procedure: Add phase A to batch tank. Begin appropriate agitation. In a separate vessel, premix phase B ingredients with appropriate agitation. Slowly add phase B ingredients to phase A with constant agitation. Stir for 30 minutes and avoid aeration. pH:7.0-8.0					
Suppliers: 1 Genovique 2 Dow 3 Interpolymer					

new acrylic polymer dispersion exhibits the quickest drying time: the drying time is approximately twice as fast as the other water-based formulations as you can see in Figure 1. The use of the new acrylic polymer dispersion improves the quality of water-based nail polishes.

If we compare the formulation containing the new acrylic polymer dispersion against the solvent-based, the drying time of the solvent-based nail polish is obviously faster but the dry-to-touch feeling of the water-based formulation is still quite impressive. This difference comes mainly from different drying patterns. In a water-based formulation the solvent dries from the top down, while the solvent-based nail polish dries from the bottom up. Also in the water-based formulation some of the water is absorbed into the fingernails.

Hardness

A second test was performed to evaluate the hardness of the film. The measure of hardness can give information about the wear resistance of the product. A soft coating is more susceptible to abrasion, scratching, and other mechanical attacks than a hard coating. A common method to measure the hardness is the Sward hardness test. This test is based on the principle that the amplitude of oscillation of the rocking device between two definite angles decreases more rapidly the softer the surface of a coating on which the test is performed.

The products with a thickness of 150 µm were applied on a glass support under controlled humidity and temperature and the hardness over a period of 72 hours was measured with the sward-type hardness rocker. One can easily measure the number of oscillations, the more oscillations that occurs the harder the film.

The results given in Figure 2 show that the film obtained with the formulation containing the new acrylic polymer dispersion is harder than the film obtained with the other water-based references. Results also highlight that the hardness of the film containing the new acrylic polymer dispersion is very close to the hardness of the film obtained with the solvent-based formulation. Therefore, the new acrylic polymer dispersion will provide excellent durability and wear resistance to nail polish formulation.

Gloss

Solvent-based products are highly appreciated for different qualities among which is their glossy appearance. The last study allowed us to evaluate the gloss of the formulation containing the new acrylic polymer dispersion against solvent-based nail polish. For each product a film of 40 µm was applied on the black portion of Leneta cards (paper with a sealer). The gloss was measured with a glossmeter which directs a light at a specific angle to the test surface and simultaneously measures the amount of reflection. The gloss was evaluated with a 20° glossmeter after the application of one coat. The 60° angle is normally used as a reference angle for the gloss measurement but because of the high gloss of the coatings the 20° angle is more appropriate in this study. The 20° angle is more sensitive to haze effects that affect the appearance of the surface.

We noticed that the gloss of the film obtained with the water-based formulation containing the new acrylic polymer dispersion is higher than the gloss of the film obtained with the solvent-based reference after the application of one coat.

Conclusion

Laboratory testing has shown that formulations containing the new acrylic polymer dispersion, Syntran PC5620, exhibit quicker drying time and superior wear and hardness compared to competitive water based nail polishes. Moreover our test formulation provides superior initial gloss compared to competitive water-based and solvent-based benchmarks.

In the light of these results, it can be concluded that the Syntran PC5620 will give a boost to the water-based nail polish market. Thanks to its unique properties, the product will allow the creative formulator new freedoms with regard to developing nail treatments and polishes, as well as, the ability to develop safe, eco-friendly, yet effective alternatives to solvent-based nail polishes. PC

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