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A High-Tech Approach to Ink Design

Desktop printers are becoming increasingly sophisticated with higher printing speeds, increased color gamut and fade resistance for photo printing, color-pigment inks, more dpis, etc. This evolution not only requires new technologies for producing new, more demanding printing systems (print head/cartridge), it also requires the ink manufacturer to evolve along with the industry, applying high technology to the development of inkjet inks.

Preliminary Issues

Before developing a new ink, consider the performance of the overall printing system, no matter whether it is based on piezoelectric or thermal principles. Also consider its limitations. If a thermal print head is used, it is essential that the inks do not cause "kogation," the formation of an obstructive coating of non-soluble crystals inside the firing chamber that is caused by some ingredients of the ink when it is heated. On the other hand, piezoelectric print heads are considered to be more robust and, in practice, they could only be affected by ink drying inside the nozzle channels.

At the same time, identify the physical and chemical requisites of the cartridges in order to avoid undesirable chemical reactions attacking any polymers or metallic components such as sponges, nozzle plates, etc.

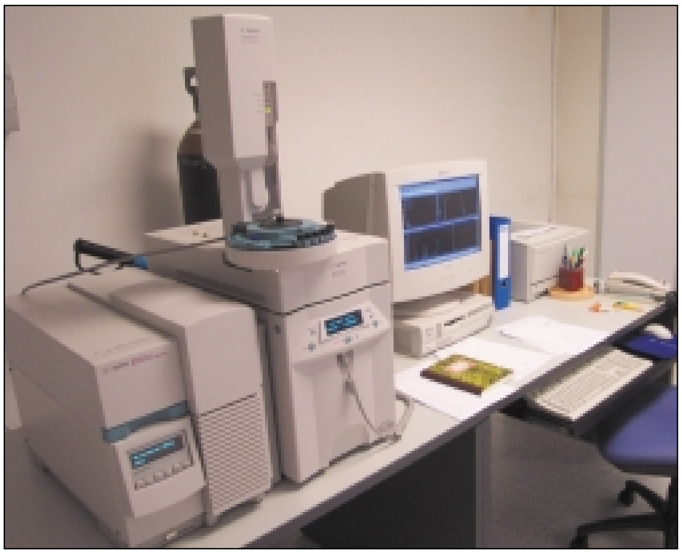
Finally, study the print media used, from low-quality paper to photo paper, transparency film, etc., taking into account the demands of the general printing performance, printing speed, color gamut, fade resistance, etc., which could determine a specific choice of raw materials to ensure the required result.

Choosing Raw Materials, Assuring Quality

The next stage is to select the most suitable raw materials to guarantee repeatability of the print quality and ensure long-term stability of the ink. Therefore, establish an optimum degree of purity and carry out exhaustive quality testing to maintain the quality.

Control all of the components of the designed formula from the main component (deionised water, "D-I water") to the additives, some of which are present in proportions of less than 0.5 percent. Test each component using an analysis protocol that is appropriate for its specific characteristics.

For example, in the case of D-I water, it is vital to control the surface tension, the conductivity and the pH, whereas for the cosolvents, the most important characteristic is their chemical purity. In the latter case, a gas chromatograph and mass spectrometer allow you to analyze each component qualitatively and quantitatively. The quantitative analysis is just as important as the qualitative analysis, because even small quantities of impurities can have negative effects on ink performance. The July issue of *Recharger Magazine* will contain a monographic article about this interesting analytical instrument, describing its potential.



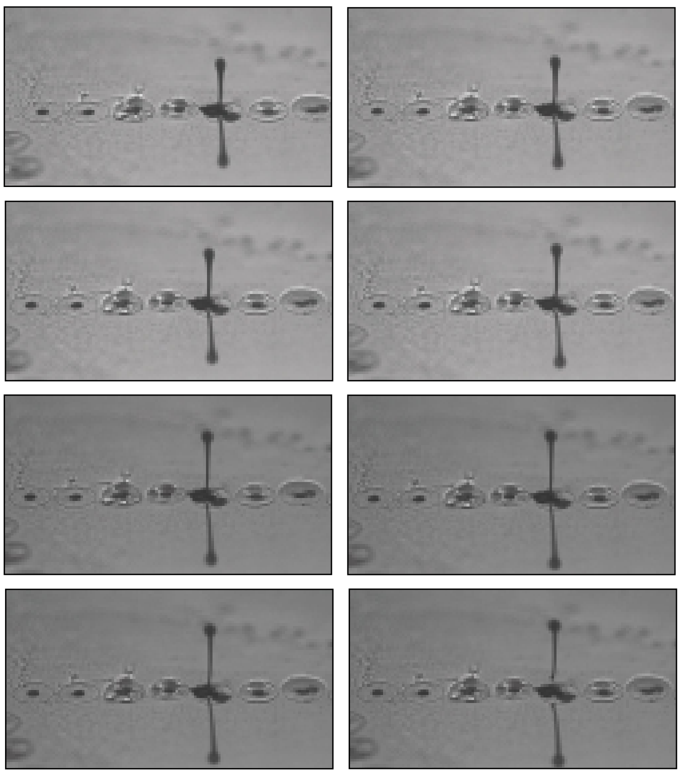
Gas chromatograph and mass spectrometer

How Does it Print? Bench Testing and Beyond

When the ink formulation is finished, analyze its performance scientifically in depth. The different parameters are: sharpness, intercolor bleeding, color gamut and optical density, fading, paper independence, drying speed, cartridge yield, stress test, etc. For a more detailed description of these parameters, see "Setting the Standards in Inkjet Ink Testing," *The Recycler*, U.K., November 2000, page 18.

Even more sophisticated analyses are also possible; for example, use high-speed photography of the ejection of ink droplets from a particular combination of cartridges and print heads to evaluate the geometry of the drops, their shape, tail and symmetry, the formation of satellites, ejection time, etc.

The following sequence of photographs shows the evolution of an ink droplet after it has been ejected. The time lapse between two successive photographs is 1 µs (microseconds), and they cover the interval from t = 31 to 34 µs and from t = 38 to 41 µs. The time origin coincides with the electrical impulse in the resistor of the thermal print head. The final image shows the drop separating from the print head.



Sequence of images showing the ejection of a droplet of pigmented ink

Photographs such as these allow us to see the cause (e.g., the satellites that are formed when the tail of a droplet separates from the body) of particular printing characteristics (e.g., over-spray).

Further Issues: How Does Ink Flow and Wet?

In fact, any incorrect appearance or behavior of the ink droplet indicates that its viscoelastic properties and its surface tension are not appropriate for the printing system, for example, the size of the nozzle, the intensity of the electrical pulse, the pulse frequency, etc.

Such mismatches give rise to poor printing performance. For example, a high viscosity will cause poor ink flow, showing starving issues. This is because the extremely fine injectors of office printers will only accept viscosities of up to 6 to 8 cPs at 25 degrees Celsius (77 degrees Fahrenheit). If the ink has a higher viscosity than this, it will not be able to flow through the injection channels. A typical ink for office inkjet printers has a viscosity of up to 5 cP at 25 degrees Celsius. Measure the viscosity using rheometers or viscosimeters.

Digital low viscosimeter with thermostat control

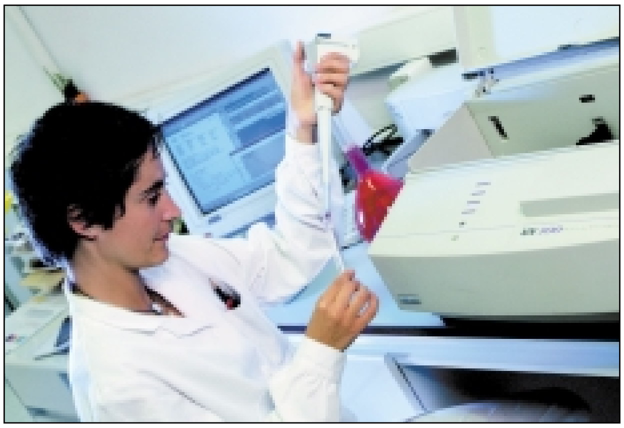
On the other hand, inadequate surface tension could cause poor or excess wetting of the sponges and the media, leading to a poor drop shape and therefore to a deficient sharpness and low optical density. Starving issues can also occur in this case. In fact, an adequate surface tension is also essential for good capillarity, that is, a good ink flow through the fine channels feeding the nozzles. The new techniques demand smaller drop size, hence control of the surface tension becomes critical. Surface tension is measured with surface-tension meter, of which several types exist.

Automatic digital ring-type surface tension meter

Color

Desktop printers use the CMYK color system (cyan, magenta, yellow and black). However, photograph printing is on the increase and additional colors are required: photo magenta, photo cyan and photo black. A broad knowledge of basic colors is also required. Some yellows are purer and others are reddish; cyans can be bluer or redder; blacks can be yellowish, blueish, neutral, etc. Each cartridge manufacturer has different needs regarding color gamut and fade-resistance, and there are even regional color requirements. A reflectance color spectrophotometer is used to measure the color gamut on the CIELAB system. To measure light resistance, xenon lamps or exposure to fluorescent light simulate outdoor and indoor fading, respectively. Fade resistance is strongly media-dependent and is also affected by climatic changes. Humidity, pollution, etc., can influence the results.

As for the production of dye-based inks, check each batch for color consistency by measuring the absorbance. This parameter allows a determination of both the color and its intensity. The most common method for measuring the color of liquid ink is to use a UV-VIS spectrophotometer. In contrast, a densitometer checks density consistency of pigmented inks.



UV-VIS spectrophotometer

Assuring Safety (and Stability)

Avoid impurities in the ink as far as possible. It is not enough to filter the ink thoroughly and check it before it is packed; the formula should minimize the risks of impurities introduced in the choice of raw materials. Bear in mind the type of printing system (thermal or piezoelectric) for the ink's application. Also consider the long-term effects of impurities to avoid problems as the ink ages.

First of all, consider ionic impurities in the ink that can be introduced through the raw materials, especially the dyes. These impurities can be measured using a conductivity meter. The data obtained (conductivity) must be analyzed with care because there are certain myths that oversimplify the issue, e.g., that greater conductivity means a greater risk of print head damage. Nevertheless, the original inks from several different cartridges prove to have all kinds of conductivity. What really matters is whether the conductivity (either high or low) is due to dangerous impurities that can affect the print head and the stability of the ink, or to a greater concentration of dyes and/or additives. To determine this point, separate ions derived from the dye from ions due to impurities, and measure the UV-visible absorbance to determine the dye concentration.

Also, ensure that the ink formula will be stable in the long term, with a suitable shelf life. One parameter to check is the pH, i.e., the acidity (pH< 7) or alkalinity (pH> 7) of the ink. By controlling this parameter, you can ensure, for example, that the dye solution will not be prone to precipitation of the dye. Dyes are among the components that are most sensitive to changes in pH. However, an inkjet ink may contain up to 10 components, each with different pH requirements.

It is also important to avoid excessive acidity in the ink so there is no corrosion in the component parts of the cartridges or the print head. On the other hand, if the ink is too alkaline, it could dissolve the glues used in some cartridges. Acidity and alkalinity are measured using a pH-meter.

Finally, perform exhaustive shelf-life testing (or aging tests) to predict how the inks will resist certain storage and shipping conditions and how long they can be used while maintaining acceptable printing performance. In general, expose the inks to high temperatures that accelerate aging effects, that is, provoke chemical reactions that can cause dye precipitation, that in turn can cause performance problems. In some cases, also expose inks to low temperatures and freeze them, and then check their print performance at room temperature.

pH-meter

Conclusion

Success in inkjet ink design is based, above all, on the interdependence between, and the fine tuning of, each and every one of the physical and chemical properties of the ink. It is also based on the proper matching of the ink to the requirements of the injection system and the expected performance. R

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