Determination of Dryness of Water-based Inkjet Ink Printing

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Abstract

The drying of water-based inkjet ink applied to media by high speed continuous forms inkjet printers, is an evolving post processing product for the printing market. The efficiency of the dryers to remove the water and glycols, semi-volatile, components of the ink can be determined by laboratory analytical techniques. Analytical methods are employed to determine the level of dryness of inkjet printed paper utilizing Thermal Gravimetric Analysis (TGA) and Fourier Transform Infrared Spectrometry (FTIR). Experimental testing methods and the resultant data are presented, showing the ability to discern the level of dryness of a water-based inkjet printed paper sample. The methods provide effective tools for analysis of drying, and point to methods by which real time in-line printer feedback may be developed to effectively improve the drying output.

Discussion: Testing Methods

Determination of the moisture content in a paper can be accomplished by mechanical “blotting” or labratory spectral and thermal analysis. Gooray [1] describes measurement of dryness in terms of “offset or smear which occurs bewteen a dried sheet of paper and another sheet of paper in a nip between two rollers”, where the offset density is measured. Lee [2] used the spectral properties of wet paper using FTIR for analysis of pulp to paper processing. Hartus [3] used thermal analysis of TGA and DSC (Differential Scanning Calorimetry) comparing rate of evaporation of ink and ink on paper to evaluate the interaction between the ink and the media. Gas Chromotography - Mass Spectra (GC-MS) is yet another useful test method that can be used with micro-extraction head space testing, to determine the amount of volitiles evolved as the inked paper is heated. Weyermann [4] used GC/MS to study the drying of ballpoint pen ink on paper. For this discussion, FTIR and TGA analytical techniques have been applied to the determination of dryness of water-based inkjet ink on paper. DCS and UV-VIS spectra were used in support of ink properties.

Samples of paper with water-based ink were tested after printing and after drying. Paper without print was tested as a control for each test. Water and glycol are the major semi-volitile components comprising the ink formulation and are foremost in the consideration of dryness of inked paper after drying. Water has strong spectral absorption peaks in the UV and in the IR wavelengths. FTIR Spectrometry shows clearly the water absorption peak in the IR at 2900nm wavelength and therefore is one of the methods chosen in the determination of dryness. TGA records the weight loss as the material is heated. TGA can determine the percent of water and other ink components that are driven off the material under test as heat is applied.

First order analysis of dryness can simply be seen by comparison of before and after drying of the paper with FTIR and TGA. Since water is the major component to be dried from the paper, an initial analysis was conducted by spreading 10 micro liters of water onto a 9 mm wide by 70 mm long (16 nano liters/ mm^2 H_2O) piece of commercial inkjet paper that has a surface coating suitable for inkjet printing. A Nicolet Magna 550 FTIR Spectrometer with ATR fixturing was used to obtain the optical absorbance spectrum. Figures 1 and 2 are data showing blank paper, water on paper, and dried paper. The paper was placed into the FTIR-ATR fixturing to give absorption peaks in reflection mode. The FTIR spectra , Figure 1, shows water’s absorption peak is at 3500 wave numbers (2900 nm), and indicates that the blank paper contained some moisture as seen with a slight rise in the percent absorbance. The water content of the paper, after applying 10 micro liters of water, is clearly seen by the rise of percent absorbance to 0.035%. The removal of the water after drying at 100°C for 20 minutes, is seen by the “concave” percent absorption at 0.010% minimum. Thermal Gravametric Analysis was carried out using a TA Instruments 2950 Analyzer. Figure 2 is the TGA data of the same blank paper and watered paper, and shows the percentage weight (% wt) loss of the water component, as the paper is heated through 250°C, of 1.5%.

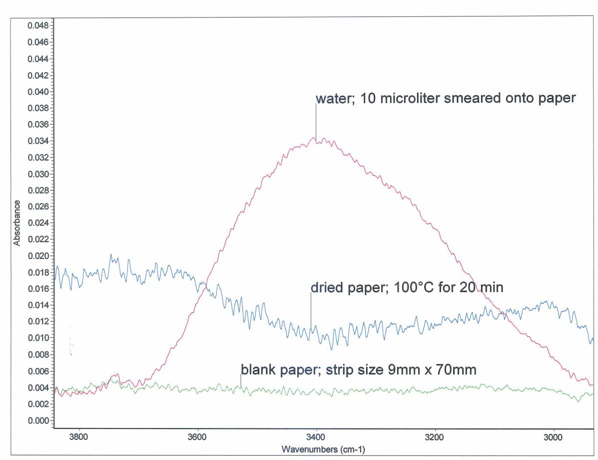

FIGURE 1. *FTIR Spectrum of 10 micro liter of water on coated inkjet paper.*

Discussion and Results of Ink Dryness Testing

Inks chosen were first analyzed by TGA to determine the temperatures at which the comprising components are evaporated and the total amount of pigments of filler. Each of the color inks have different volume, percent by weight, of water and glycols , semi volitile components. The variation of percent water will affect the rate of evaporation of each of the inks or combinations thereof.

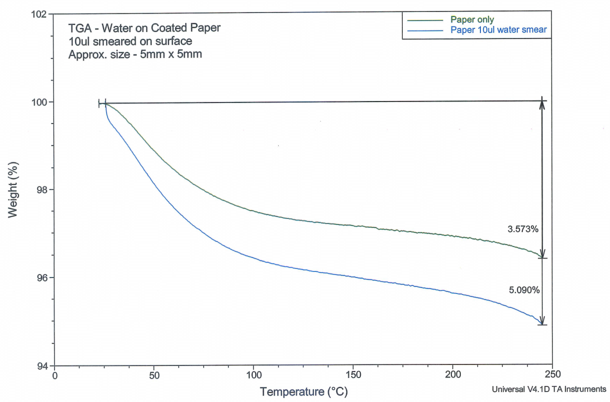

FIGURE 2. *TGA of blank coated paper and paper with 10 micro liter water*

Each of the inks were heated through 800°C to determine the evaporation temperatures and percentage, by weight, of all the ink components, including pigments. In addition, mixtures of known ink components were mixed in different ratios and TGA performed on those mixtures to help further characterize the data on each ink. These TGA tests were conducted to provide baseline information on the inks to be studied. In addition Infrared spectrometry, FTIR, was performed on each of the inks to help further identify components of the inks. Furthermore, UV-VIS spectral analysis and Differential Scanning Calorimetry (DSC) were used to identify optical and thermal properties, of each of the inks. DCS analysis provided the glass transition temperatures and heat flow of each ink, providing information to better understand the inks in the drying process.

Commercially available ink, used in a high speed production inkjet printer, was chosen for this study. As described in the proceeding section, each of the color inks were analyzed for the percent of water and glycol components. Each ink was then applied to a standard coated inkjet paper, 9mm x 70mm dimentions, in the amount of 10 microliters across the surface. The inked papers were analyzed before and after drying for the change in moisture content of a know amount of ink deposited upon a measured area.

Figure 3 is a TGA analysis of the magenta ink, showing the relative percent by weight of the water and glycol components. From the TGA analysis performed on each color ink, the percent , by weight, ratios of water and glycol contained in each ink were determined. Table 1 is a summary of the primary color inks and the weight ratios of water and glycol obtained. Black ink, as given in Table 1, has a water content of 74% and the glycol 8% by wt. The remaining percent are high temp volitles and ink pigments.

10 micro liters of black ink was applied to a 630 mm^2 strip of paper (16 nl/mm^2), and was placed into the FTIR-ATR fixturing and tested. A small piece of the inked paper, 25mm^2, was tested with the TGA to temperature of 250°C. Figure 4 is the resultant FTIR spectra and figure 5 is the TGA plot. Each shows moisture reduction.

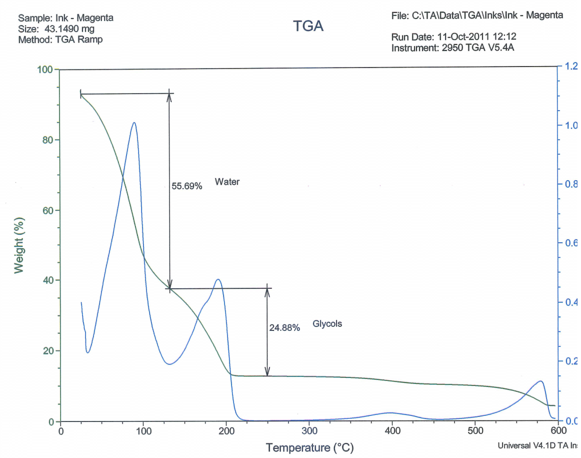

FIGURE 3. *TGA of magenta ink showing percentage of water and glycol components in the ink.*

INK	% Water	% Glycol
Magenta	55.7	24.9
Cyan	58.1	24.9
Yellow	63.5	22.8
Black	74.4	8.5

Table 1. *Percentage of water and glycol content.*

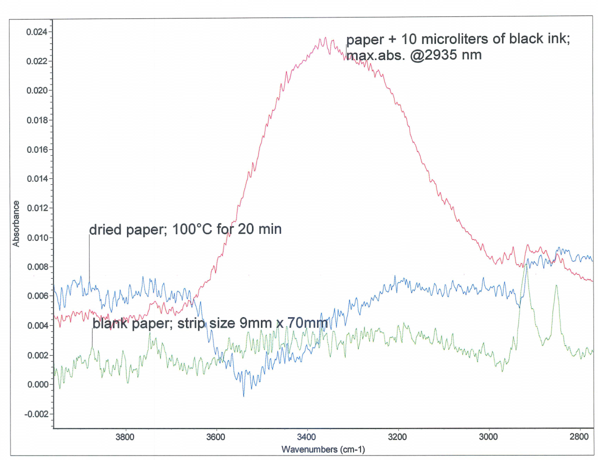

FIGURE 4. *FTIR spectras of water content of blank paper, black ink on paper, and dried black ink.*

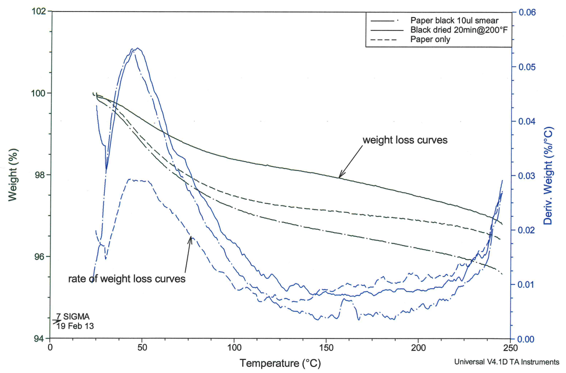

FIGURE 5. *TGA plot of water content of blank paper, black inked paper and dried ink paper.*

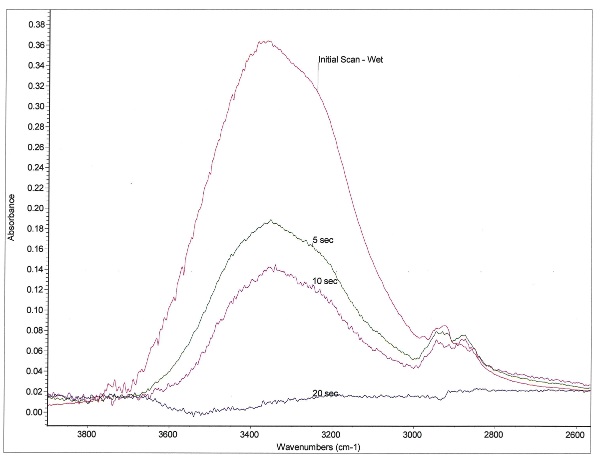

FIGURE 6. *FTIR absorbtion plots of IR lamp drying of black inked paper.*

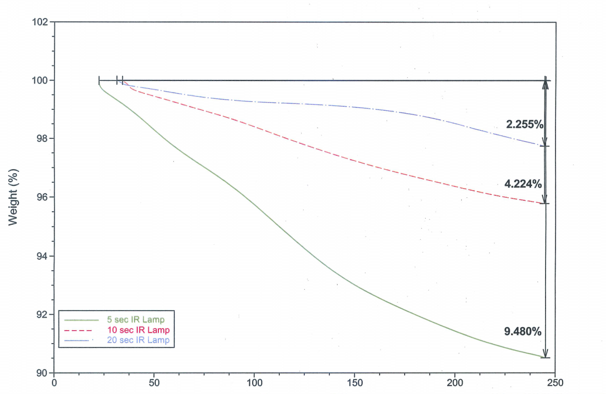

FIGURE 7. *TGA plots of IR lamp drying of black inked paper.*

To simulate an infrared lamp drying system, samples were subjected to IR radiation, using a Therma-tech CH40 Infrared heater, with operational wavelength 2600 to 6000 nm and 40 watts per inch of power . The samples, with 10 micro liters of black ink, were held under the IR lamp for 5, 10 and 20 seconds. Figure 6 is the FTIR composite analysis for that test, showing dryness vs exposed time. Figure 7 is the TGA of the samples, giving the relative percent weight loss of moisture for the 5, 10 and 20 seconds drying time of the inked paper.

Conclusion

FTIR and TGA techniques are viable laboratory techniques that provide analysis of the effective dryness of inkjet printed substrates. In this study, the dryness of water based inkjet inks on paper was analyzed by FTIR-ATR techniques and confirmed by TGA. The use of FTIR spectral analysis to achieve a relative relationship of dryness is shown to be an effective tool. Supporting data using TGA provides a numerical value of the volume of moisture that is contained within a sample of inked paper. Inferrence to the amount of moisture within a sample can then be applied to the FTIR absorption efficiency.

Infrared spectral analysis could be applied to an optical system which is integrated into the printer drying system, providing real time feedback, as to the effectivness of the drying system employed. Development of an IR spectra analysis system [5], is achievable using IR laser diodes (or LEDs) and corresponding IR photodiodes, operating at 2900 nm and 3100 nm wavelengths, covering the absorption spectrum of water and glycols. The proposed system will, like the FTIR analysis presented in this study, provide a relative value of moisture content of the paper as it passes under the interagation light. The resultant signal from the photodiodes would be processed by a controller unit which then would direct the heating system to raise or lower the power needed to achieve effective drying.

References

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[4] C. Weyermann, "A GC/MS Study of the Drying of Ballpoint Pen Ink on Paper", Forensic Science International, 168 (2007) 119-127.

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