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Attension [Application Note] 2

Tensiometry in Inkjet Printing Applications

This application note illustrates how the Attension Theta Optical Tensiometer and its picoliter dispenser can be used to study and develop inkjet printing technologies.

Introduction

Inkjet is a relatively young, but expanding printing method. Inkjet is based on digital information transfer, in which an image is formed by ink-droplets that are ejected directly from the printing head at high speed onto the substrate either by drop-on-demand or continuous mode technologies[1]. This gives freedom to personalize each printed product and provides print-on-demand processing, which is not possible with the currently dominating non-digital fixed format printing methods, such as offset. A major advantage of inkjet is also its versatility; it can be used with varied combinations of ink type and substrates. Typically, inkjet is used in small scale color printing and in low-cost data printing applications, for example in home and office printing. However, due to its advantages compared to conventional printing methods, it has become common also in the industrial printing and packaging industry[2]. Inkjet printing is also utilized in emerging functional printing applications, for example in printed electronics.

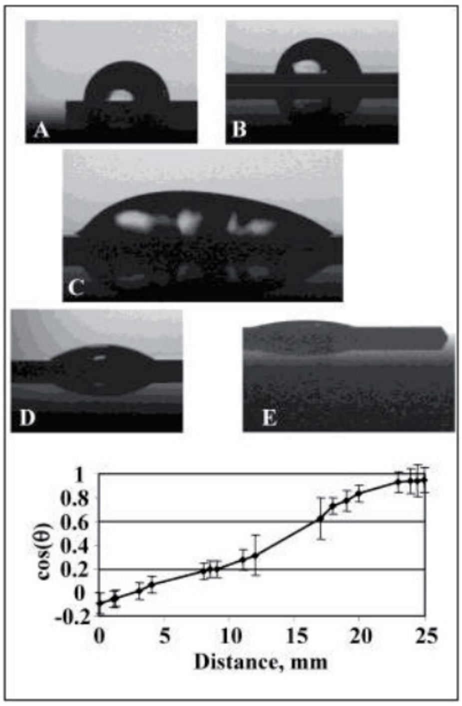
Inkjet print quality is highly dependent on the properties of paper and ink and their interactions. The main components of inkjet inks are vehicle (water, solvent, oil or UV-based), colorants, binders and additives. Typically, inkjet inks display very low viscosity (2-30 mPas) and surface tension is adjusted between 25-40 mN/m. The inks can be divided by the type of colorant into dye-based and pigment-based inks. Since the inkjet inks are very penetrative and low viscous, it sets a high demand on the surface properties of substrates. Surface energy, charge, roughness and porosity are the key elements defining inkjet print quality.[1,2]

Tensiometry is widely utilized to study the wetting phenomena in inkjet printing applications [3–6]. Surface tension of the ink and surface free energy of the substrate are important parameters in defining the wettability and adhesion between ink and substrate. Since the image is created by the ink-droplets, the contact angle measurement is a useful tool to demonstrate the inkjet printability. The contact angle analyses allow to study the droplet spreading and absorption via analyzing the drop dimensions and contact angle with time.

Theta optical tensiometer

Case study 1: Characterization of patterned self-assembled monolayers and protein arrays generated by the ink-jet method

Inkjet technology has been widely used to deposit various functional patterning, such as DNA microarrays, polymer deposition, gold conductive tracks and optical microlens arrays. Pardo et al.[3] used Attension's (former KSV Instruments) optical tensiometer, CAM 200, to characterize the patterned protein films on gold substrate. They demonstrated that drop-on-demand (DOD) inkjet technology is suitable to print proteins and thus opens the possibility of generating inexpensive and dense bioarrays for example cell-based sensors. Water contact angles results showed that the DOD method was able to create chemical gradient by changing the spatial density of the droplets (Figure 1).



[Figure 1]: Cosine of advancing water contact angle as a function of distance. The distance is measured from the sample edge, from where the spatial density of protein array changes gradually[3].

Case study 2: Spreading and absorption of pigment-based inkjet ink on paper and polymer substrates demonstrated by picoliter drop contact angles

Picoliter sized droplets offer many advantages for various applications. Improved spatial resolution makes it possible to characterize surfaces on much smaller areas, for example on microarrays and single fibers. Theta optical tensiometer combined with its picoliter dispenser enables picoliter drop formation by using the piezo-driven inkjet technology. Therefore, the picoliter dispenser allows improved ability to demonstrate the real inkjet printing process compared to standard dispenser utilizing typically a few microliters drops.

In the following demonstration the picoliter contact angle measurements were performed on coated inkjet paper (HP, Everyday Photo Paper, 170 g/m^2) and on low density polyethylene (LDPE) extrusion-coated paper. The surface free energy of the substrates was defined by measuring the contact angles on both substrates with water, diiodomethane (DIM) and ethyleneglycol (EG). The surface energies were calculated by the Theta SFE software using the extended Fowkes[7] and the acid-base approach by van Oss et al.[8]. Results are shown in Table 1. Commercial pigment-based inkjet ink (HP 56, black) was used as an ink and drop size was 180pL. Since the inkjet inks have low viscosity, the absorption phenomena may be extremely fast especially with porous paper substrates, that is why Theta was also equipped with a high speed camera (1550 fps).

Figure 2 shows the contact angles with time on two different substrates. The initial contact angles with both substrates are quite similar. With non-porous polymer surface the contact angle

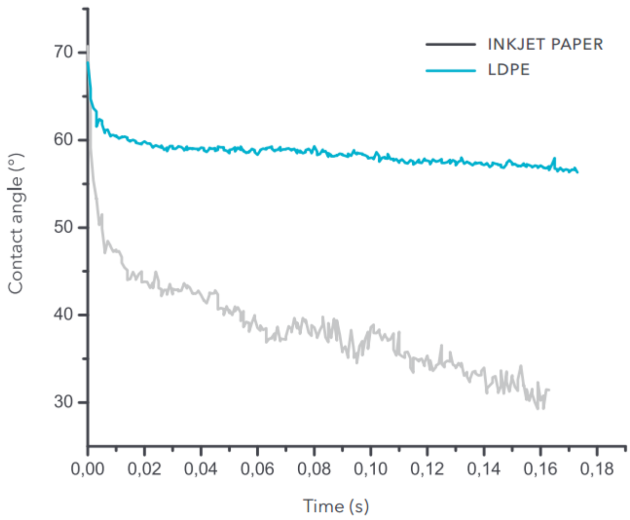
		LDPE	inkjet paper
Contact angle	water	101,2	28,8
	DIM	73,4	33,6
	EG	53,6	35,2
Surface energy	γ^{tot}	31,5	59,7
(Extended Fowkes)	γ^{d}	31,3	31,9
	γ^{p}	0,2	27,7
Surface energy	γ^{tot}	32,5	45,7
(Acid-base)	γ^{LW}	32,2	41,9
	γ^{AB}	2,2	3,8

[Table 1]: Cosine Contact angles, surface free energy and its components (γ^{tot} = total surface energy, γ^{d}/γ^{LW}=dispersion component and γ^{p}/γ^{AB}= polar component) on the LDPE-coated paper and inkjet paper measured with Theta optical tensiometer.

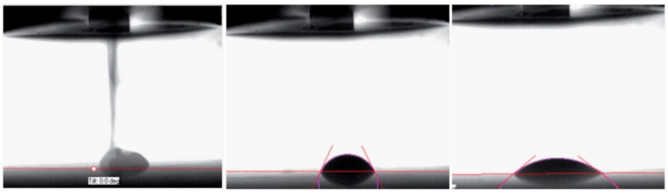
decreases slightly with time due to spreading of the droplet, after which it stabilizes. With inkjet paper the fast decrease in contact angles shows the absorption of ink droplet into porous paper media.

Conclusion

Inkjet printing is a versatile technique used in wide range of applications from small scale home and office printing to high speed industrial printing and more novel functional printing applications. Since the interactions between ink and substrate are crucial to define inkjet print quality, tensiometry is widely utilized in this field. Adhesion between ink and substrate can be estimated by comparing the surface tension of the ink to surface energy of the substrate. Absorption and spreading of droplet are studied by contact angle measurements. A novel picoliter dispenser option for Theta optical tensiometer allows the same size range droplet formation as in real-life inkjet process by using piezo-driven technology.



[Figure 2]: Picoliter contact angle with time measured on inkjet paper and LDPE-coated paper using the Theta Optical Tensiometer combined with its picoliter dispenser.



[Figure 3]: High speed camera enables to measure the initial picoliter drop contact angle right after the drop hits the surface and then the fast spreading and absorption phenomena.

References:

[1] Leach, R.H. and Pierce, R.J. (1999), The Printing Ink Manual, Fifth Edition, Dordrecht (Netherland), Kluwer Academic Publishers, 993P.

[2] Svanholm, E., (2007), Printability and Ink-Coating Interactions in Inkjet Printing, Doctoral Thesis, Karlstad University, Sweden.

[3] Pardo, L., Wilson, W.C. and Boland, T., Characterization of Patterned Self-Assembled Monolayers and Protein Arrays Generated by the Ink-Jet Method, Langmuir 19 (2003), 1462–1466.

[4] Arin, M., Lommens, P., Avci, N., Hopkins, S.C., De Buysser, K., Arabatzis, I.M., Fasaki, I., Poelman, D. and Van Driessche, I. Inkjet Printing of Photo-catalytically Active TiO2 Thin Films from Water Based Precursor Solutions, Journal of the European Ceramic Society 31 (2011), 1067-1074.

[5] Roth, E.A., Xu, T., Das, M., Gregory, C., Hickman, J.J. and Boland, T., Inkjet Printing for High-Throughput cell patterning, Biomaterials 25 (2004), 3707-3715.

[6] Saarinen, J.J., Ihalainen, P., Määttänen, A., Bollström, R. and Peltonen, J., Printed Sensor and Liquid Actuation on Natural Fiber Based Substrate, NSTI-Nanotech, Vol 2 (2010), 527–530.

[7] Fowkes, F.M., Determination of Interfacial Tensions, Contact Angles, and Dispersions Forces in Surfaces by Assuming Additivity of Intermolecular Interactions in Surfaces, J. Phys. Chem. 66 (1962) 382.

[8] van Oss, C.J., Chaudhury, M.K. and Good, R.J., Interfacial Lifshitz-van der Waals and Polar Interactions in Macroscopic Systems, Chem. Rev. 88 (1988) 927.

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