New Opportunities in Digital Industrial Printing for High Volume and Niche Markets

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Introduction

In this paper, we consider two different projects that have been performed successfully in close collaboration with all parties. The first one is on color printing on industrial substrates with a medium resolution. In this case, we show how the nature of ink lead to largely different printed qualities because of not fully controlled ink-media interactions. The second project has to do with the digital fluid jet deposition of conductive lines on various substrates. In this case we first describe the basic principles and the material and equipment used before detailing the results.

Ink-Media Interactions

In this section we successively describe the equipment used to visualize the drop impact phenomenon and the associated results. This section is focused on the analysis of impact process for the described drop forming device. There is need in identifying and rejecting correctly heads or inks which may present printing problems. The required performances[1] for the print-heads could be in terms of drop sizes, for the inks in terms of optical density, color gamut and uniformity and so on and for the media in terms of drops impact, spreading and absorption behavior. It is well known in the existing literature that critical issues in print quality are the coalescence of ink on the print media[2,3] and/or imperfections related to the manufacturing of print heads.[4] The overall expected performance[5] is to precisely determine the relationships between ink and print media. The substrates used are very different from one another and the challenge is to define a precise link between print quality and the entire drop ejection and impact process.

Visualization set-up

For this purpose, we have developed a drop visualization apparatus[6], which allows us to evaluate the dynamic of the drop impact. This apparatus is based on the pseudo-cinematography technique[7]. It is used for the analysis of a single drop impact, recoiling and spreading. This system has a comprehensive set of built-in electronics, optical and mechanical hardware, which allows taking very high magnification computer controlled photographs at different times. A global view of the visualization apparatus is presented elsewhere.[6]

The experimental observations and analysis procedures have been designed to obtain both qualitative and quantitative information on the transient shapes of the impact of the liquid drop.

Results

The first experiments have been performed with large drops exiting from a syringe. The pseudo-cinematographic technique allowed us to follow the dynamic of the same drop impacts (2.5 mm diameter water droplet) on two different substrate: hydrophobic and hydrophilic (figure 1). These experiments are emphasis the importance of a dynamic study of ink media interaction since it can be noticed that the first stage of drop spreading are similar for both substrate while the final drop shape are very different. This behavior will have to be taken into account in the case of several droplets impacting next to each other.

We have then performed experiments in the case of small droplets coming from a commercial printhead. The main parameters in which we are interested are shape of the drop as a function of the initial perturbation. Indeed this may have consequences on the printed spot and we give in figure 2 their evolution versus the input voltages.

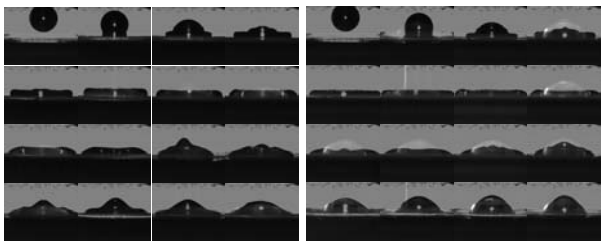

Figure 1. Dynamic of drop impact on 2 substrates

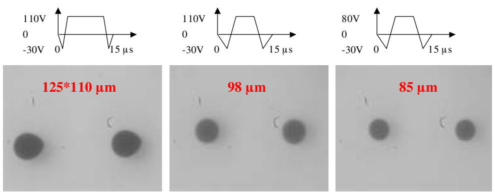

Figure 2. Waveforms and associated printed spots

We can notice that the waveform has an important influence on the size and shape of the printed spot. Indeed for the first waveform the amplitude of the voltage is high (110 volts) and the holding time is long (about 13 µs). This leads to long filaments which are not completely retracted in the drop at the time of impact and so the printed spot is ellipsoidal with 125 µm for the long axis and 110 µm for the short axis respectively. For the third case, the waveform has been optimized and this leads to perfectly rounded drops with a diameter on average of about 85 µm.

Conclusion

In this section, we have first presented specific tools for visualising and characterising drop impact. The pictures recording have been performed with resolutions of the order of microseconds. The impact measurements have been performed by varying the waveform. We have demonstrated experimentally that this has important consequences on the printed spot because of the associated tail lengths so it may be useful to consider the optimisation of the triplet print-head/ink/media with the form of the input signal.

Conductive Line Depositions

The range of possible markets for drop on demand ink-jet printing is growing with applications in a number of areas. Among them, one can cite the conductive line deposition by ink-jet printing.[8] This promising technology may be used in a huge number of applications for interconnection, antenna or electrode deposition purpose. Compared with other electrical conductive devices such as copper etching or wire bonding, it shows very interesting perspectives such as versatility, very fine pitch and high potential throughput.

Process Optimization

Our first goal has been to customize the standard ink-jet printing process for this new application. We first have set the specifications for the development of the conductive ink and we have selected the most suitable print-head to eject the ink without clogging. The ejection process has then been optimized by adjusting the waveform applied to the piezo-electric elements. The figure 3 give an overview of what can be done in terms of drop volume control and the resulting track width, with a given fluid and print-head, only by changing the waveform.

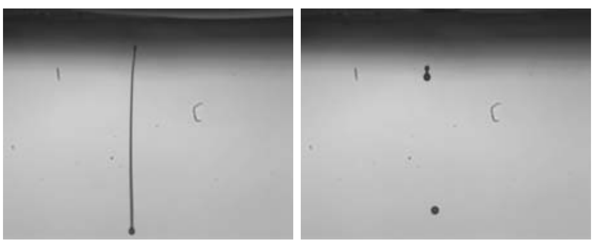

Figure 3. 14 pl and. 9 pl, (90µm and 51µm wide drop impact)

Interconnection

With the optimized process, we have printed conductive lines on different substrates and we have measured the width and conductivity. Lines with 200µm width and 2 Ω conductivity on 2mm length have been printed with a single pass process. One of the application of this technology concerns microchip interconnection. So, we have printed the drawing shown in figure 4 on a microchip glued on kapton. The printing frequency was 4 kHz and the velocity was 0.12m/s. The resulting interconnected module is shown on figure 4. The conductivity between the bumps and the copper has been achieved with low resistance values (less than 10V).

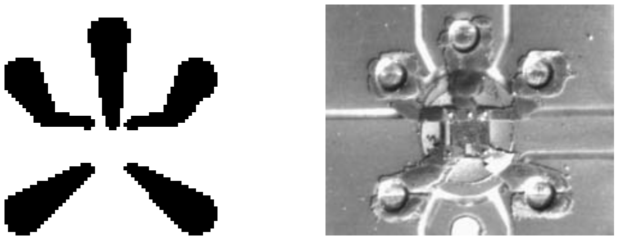

Figure 4. Pattern to be printed and printed pattern.

Conclusion

This section presents a new process for depositing conductive lines by the mean of ink jet printing technology. This process has been achieved by a selection of the most relevant components, especially ink and print-head, and by an accurate adjustment of the process parameters. This innovative technology is now available for low cost and versatile conductive line production for different fields of electronics and micro-electro-mechanical systems manufacturing.

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Biography

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