[Technical Paper]

# Issues and Approaches Imposed on Ink Jet Technologies for the Progress of Printed Electronics

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**Abstract**

The simplicity of the ink jet process has led to major changes in electronics packaging in what is known as printed electronics. Major changes here means drastic cost reduction relative to the long-term trend, and also creating a new performance axis (flexibility, customization, large area, little environmental load … namely added value). However, simplicity has two sides: '*Possibility*' and '*Limitation*.' For the past several years, '*Possibility*' has been attracting a lot of attention, but in the coming years, if ink jet technology does not overcome '*Limitation*', the real change will never occur.

In this paper, the related issues and status of approaches resolved by ink jet printheads or the printing process are described for the further progress and practical application of printed electronics using ink jet technologies.

These issues can be categorized into 1) ejecting processes of functional liquid, 2) drop landing and dot (film) formation on the substrate, and 3) maintaining printhead reliability. In particular, expanding the range of applicable liquids, further miniaturization of the ejected liquid drop, and improved accuracy of dot positioning are strongly required for printheads.

In printed electronics, unlike with desktop ink jet printers, impermeable media are often used, so analysis and control of the behavior of the liquid on the substrate are also important. Furthermore, technologies for maintaining stability in the ejected drops make a difference.

These novel activities for improving ink jet issues will face tough problems and need revolutionary approaches, but a great innovation in printed electronics using ink jet technologies can be expected when success is achieved.

**Keywords:** Ink Jet, Printed Electronics, Drop Volume, Liquid Latitude, Viscosity, Airflow, Self-Alignment

## 1. Introduction

Applications of ink jet technologies outside of printing equipment have been investigated for a long time because of the simplicity of the ink jet process. In the past ten years, nobody has doubted that printing electronics using ink jet technologies is one of the most suitable applications to develop the characteristics of ink jet to their fullest.

Figure 1 shows a Portfolio of applications producing value by adopting ink jet technology, categorized by the features of ink jet they require.[1] As shown in this figure, applications in various fields, including printed electronics, have been investigated and developed. However, in spite of these efforts, most of the applications have neither appeared in our ordinary life nor yet been successful in business, with a few exceptions.

There is a famous quote representing the gap between the possibility and the reality (the limitations of ink jet) in the Printed Electronics region.

"Ink jet can make everything, but have manufactured

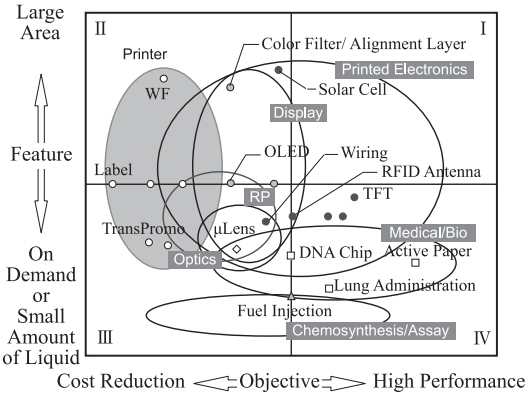


Fig. 1 Application of ink jet to digital fabrication.[1]

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# Evolution Theory of Ink Jet Technologies: Progress by Component or Architectural Knowledge

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**Abstract.** *Ink jet technology has extended its market by upgrading functions and improving performances of a few key components (printhead, ink and media) under a simple marking process for years. However, this trend has been saturated in the personal market, and the market has been stagnant. In this situation, two directions for ink jet technology progress have become obvious. One is expansion of the ink jet to various applications such as digital fabrications utilizing a simple process and the other is facing challenges (to the commercial printing market) from performance limitations derived by imaging processes that are achieved only by the interaction between ink and media. The differences of technical approaches in each direction also exist. The progress of an elemental technology region (key components) has been noticeable in the expansion of the possibility. The challenge to the limitation has been effective in the progress of system integration or peripheral technology. The former evolution (Concentrating Functions Progress) can generate "Incremental Innovation" and needs component knowledge to improve component performances. The latter (Sharing Functions Progress) demands architectural knowledge to test the optimum combination of components maximizing system performances and is one of the driving forces generating "Architectural Innovation". Generically, venture companies or small start-ups play a role in Architectural Innovation because they are free from resource allocation mechanisms or an organizational form for Incremental Innovation. But in the current commercial printing market, many big companies have introduced ink jet printers with different component combinations (architectures) and the Dominant Design has not been fixed yet. The shift from Incremental Innovation to Architectural Innovation has also occurred in additive manufacturing.* © *2018 Society for Imaging Science and Technology.*
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## 1. INTRODUCTION

In 1968, the first commercial ink jet printer "Videojet" was introduced into the market. There were some ink recorders said to be the beginning of the ink jet printer such as Kelvin's siphon recorder (1876) or Elmqvist's mingograph (1952). Based on my definition of ink jet given in the next chapter, "Videojet" is considered the first. For that reason, 2018 is the 50th anniversary of the appearance of the ink jet printer. Figure 1 shows the macrotrend of the ink jet printer from its birth to the present. Many printers with small size have been developed and commercialized in the early phase. Second, ink jet printers provide high image quality using small ink drops, diluted inks, and specialized ink jet papers. With the advent of pagewide printheads, ink jet printers have been able to enter the high printing speed market such as high-end office and transactional printing. Today, ink jet printers with high image quality and high printing speed have entered the commercial printing market.

In this article, technology progress of ink jet is expounded. In particular, configuration of technology progress is analyzed and categorized. Market backgrounds requiring each configuration are also explained. Future directions of these progress configurations and difference of innovations created by each configuration are indicated. Finally, technology progress is associated with innovation portfolio, and some suggestions are derived.

## 2. DEFINITION OF INK JET TECHNOLOGY

The definition of ink jet technology proposed by the author is as follows [1]:

*Dropletize liquid including colorants or functional materials, and eject liquid drops to recording target (media) on demand from image (pattern) signal, then bring colorants or functional materials to recording target (media).*

Defining technology is important to identify invention of course; not only that, it is important to consider extensions and applications of technology. As is clear from this definition, ink jet is not a technology only to realize printers.

The marking process by ink jets is very simple in either serial printers or line printers with pagewide printhead, and ink jets have many merits such as small size, low cost, small power consumption, high process stability and high scalability, which come from simplicity of marking process. The simplicity of the ink jet process leads to the high possibility of applying ink jets to various applications but it also imposes limitations. This is because the marking process is achieved by only an interaction between ink and media. These two aspects are fundamental to my ink jet evolution theory described here.

## 3. CONCENTRATING FUNCTIONS PROGRESS (CFP)

Under a simple marking process completed with only a few key components of printhead, ink, and media, these key components have led to the progress of prime performances of printers. The prime performances of printers are absolute image quality and printing speed. Printhead performance progresses contribute to printer performance progresses, and ink performance improvements lead to printer performance

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