Industrial inkjet technology

Fujifilm printhead, ink and system integration technology for industrial and package printing
Advanced inkjet technology development

The Fujifilm inkjet technology group is formed of three Fujifilm companies: Fujifilm Dimatix who manufacture inkjet printheads, Fujifilm Imaging Colorants who produce water based inks, dyes and pigment dispersions, and Fujifilm Speciality Ink Systems who specialise in UV and hybrid inkjet inks.

These companies work to develop advanced inkjet technology and are supported by research groups based in Tokyo, Japan and Cambridge, UK. These research groups include the Fujifilm Advanced Marking Research Laboratories and the Synthetic Organic Chemistry Laboratories who are based in Tokyo and develop core technologies. They provide innovative dispersion technology as well as the synthesis of a number of unique materials that form a key part of the Fujifilm inkjet portfolio of technologies. In addition, there is a group in Cambridge that works on system development, refining technologies such as bespoke waveforms and drying and curing systems, and pushing the limits of what is possible.

The Fujifilm inkjet group companies command an impressive array of technologies and are widely acknowledged as owning one of the most extensive intellectual property portfolios of any company operating in the inkjet arena.
Inkjet is moving into mainstream industrial and package printing and the combined resources of the Fujifilm inkjet technology group are focused on addressing the specific challenges that these new technologies pose.

To understand these challenges and the methodology that Fujifilm is employing to address them, it is useful to consider the particular needs of the industrial and package printing businesses. The range of materials being printed is vast and the range of applications is diverse, but many of the requirements are common. Viewing distances are typically short and quality expectation is high, so spatial resolution of print must also be very high. Inks must have a defined functionality such as adhesion and resistance properties in order to provide the end use properties that are demanded by the application, which are frequently enshrined within rigid specifications. Finally, production volumes are typically large, requiring high speed printing. It is this combination of high print resolution, ink functionality and print speed that define the task for Fujifilm’s inkjet technology group.

The challenges that this poses are staggering. A high speed digital printer may have to place up to 15 billion droplets of ink accurately, every second in order to form a high resolution image at production speed. Achieving this and doing so with a specially designed ink that has all of the required end use properties is a significant challenge, requiring a combination of advanced technologies in order to provide a final solution.
100 microseconds in the life of an inkjet droplet

It takes around 100 microseconds for a typical inkjet droplet to be formed, travel to the substrate, land on the surface and start forming the image.

In this time, an Olympic sprinter will run 1mm, and a Formula 1 race car will travel less than 1cm.

In the inkjet printer itself, an individual nozzle may fire up to a further 10 droplets of ink while the first droplet is still in flight. To understand the technologies needed to make this happen and how these technologies work together, it is useful to consider what is actually going on while an inkjet droplet makes its journey from nozzle plate to substrate, and to review the technology that makes all of this possible.

100 microseconds

The time it takes for an inkjet droplet to form an image. That’s all the time Fujifilm technology needs.
The diagram below shows inkjet droplets in flight and details some of the characteristics of the various components that must all be tuned in order for the overall operation to be optimized. There are a great many of these properties that have to work together in order to obtain the best overall performance so it is useful to split these into three groups:

- **Jetting performance** - properties needed in order to produce an inkjet droplet that is correctly formed and travelling at the right speed in the appropriate direction.

- **Ink functionality** - the properties that ensure correct image formation on the substrate and determine the final properties of the product.

- **System reliability** - all of the factors that need to be considered in order to make sure that the printer is completely reliable.

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Jetting performance

The printhead is the heart of any inkjet printer, and the design and construction of the printheads determine a number of key properties including spatial resolution, print speed and ink deposit. Fujifilm industrial printheads are designed for a range of applications, and versions are available that are compatible with most common ink types including UV, water based, hybrid and oil based systems.

Once the printhead has been integrated into a suitable system, it receives ink at the correct temperature and flow rate from the ink delivery system.

The printhead is also fed with image data that tells the head when to fire a droplet, and a waveform that tells it how to fire the droplet. Finally, the environment including temperature and pressure is regulated to ensure optimum performance.

The fluid characteristics of the ink itself are carefully matched to the printhead in order to optimize drop formation. These fluid characteristics are what makes the droplet round, and keep it moving in the right direction without breaking up, ensuring that satellite or mist formation is minimised.

The ability to match printheads and inks for a particular application and to tune waveforms to optimize jetting performance is a key Fujifilm technology, and this is illustrated below.

This, together with the ability to tune the fluid characteristics of the inks mean that Fujifilm is able to optimize jetting performance and ensure maximum performance and reliability.

Waveform development

A waveform is a series of electronic signals that are used to fire an ink droplet from a drop-on-demand piezo printhead. It determines everything from the size and velocity of an inkjet droplet to the speed of printing and is a major contributor to overall system reliability.

This diagram shows a series of waveforms that would be used to produce droplets in a greyscale printhead. Each of the larger pulses starts to eject a droplet that combine on the nozzle plate to form a large droplet. A ‘cancel pulse’ can be included to break the droplet off cleanly, minimising satellite and mist formation.

Waveforms have to be precisely tuned to the dynamic response between the ink and the printhead itself, and Fujifilm is able to create highly optimized waveforms due to its in depth knowledge of printheads and inks.
**Printheads**

Fujifilm Dimatix produce a range of inkjet printheads for industrial and package printing applications as well as established wide format graphic printing. These class leading printheads employ a range of proprietary Fujifilm technologies and combine these properties to produce some of the best and most reliable printheads available today. These technologies include:

- **Redijet technology** incorporating ink recirculation past the nozzle for quick start up, long standby times and reliable operation
- **Fujifilm non-wetting nozzle plate coating**, reducing contamination and helping to maximise up time with high duty cycles
- **Silicon MEMS architecture** allowing ‘printhead on a chip’ construction, maximising nozzle density and minimising drop size
- **Versadrop variable drop management**, allowing greyscale printing to enhance visual print quality
- **High frequency operation** providing high speed printing
- **Compatibility with most inkjet ink technologies** including water based, UV, hybrid, oil based ceramic and the associated maintenance fluids
- **Unique Fujifilm piezo ceramic** with superior piezoelectric performance

![Fujifilm Starfire™ printhead for high volume printing with most ink types](image1)

![Fujifilm Samba™ ultra high resolution, high speed MEMS printheads, designed to be compatible with most ink types](image2)
The properties of the finished print are determined to a large degree by the chemical make-up or ‘functionality’ of the ink. These properties include all of the end use requirements such as colour, adhesion and resistance properties together with any specific properties that may be needed for the end application. In addition, the chemistry of the ink plays a major part in the way that the image is formed.

Many of these properties come into play a fraction of a second after the inkjet droplet has landed on the substrate. During this time, the droplet has to wet the surface by a predetermined amount so that the image is formed correctly, and has to start the process of bonding with the surface. A short time later, the ink needs to dry if it is a water based ink, or cure if it is a UV system. It is during this process that the properties such as chemical and physical resistances are formed. The lightfastness is determined partly by the selection of the pigment, and partly by the balance of the ink system, so these properties are incorporated into the design specification for the ink. Pigments have to be dispersed into the ink, and dispersion science is a key Fujifilm technology.

All of the components in the ink have to be tuned to each other as the overall performance requires everything to work together.

**Inks for industrial applications**

Fujifilm produces a range of UV and water based inks for a variety of industrial and package printing applications. This includes inks for labels, flexible packaging, corrugated packaging, textiles and decorative laminates. In addition, there are specially designed inks for specific applications including ultra-high lightfast inks for exterior design, thermo forming inks and inks for glass and other difficult materials.
**Pigment Dispersion**

Dispersing pigments to a precisely defined particle size, and keeping the individual particles separate is a vital part of inkjet ink formulation. It is essential for jetting performance and print consistency as well as final performance of the ink. Fujifilm has a number of unique technologies that have been developed to optimize dispersion. The mechanism is illustrated in these diagrams and while the implementation of the technology varies depending on whether the ink is water based or UV cured, the principle is generally followed.

Pigment particles are separated by milling, and a dispersant is used to both link the pigment with the vehicle in which it is dispersed, and keep the particles separated.

In the case of UV dispersions, Fujifilm technology is used to create unique dispersants that are used in a precisely controlled manufacturing process. Waterbased dispersion technology allows design flexibility; the polymer dispersant is absorbed onto the pigment surface and cross-linked to create high stability.

- **Ink binder**
- **Bonding agent**
- **Dispersion coating**
- **Pigment**

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When Fujifilm designs an ink, it starts with the colour - the pigment dispersion. This is combined with other liquid components to impart the finished ink properties and enable it to be dried or cured.

Optimizing pigment particle size is key to developing good inkjet inks.
System reliability

System reliability is critical for inkjet printers as they are true binary devices in every sense of the word, and therefore either work well or not at all. There are two aspects to system reliability:

- **Sustainability**, where the printer will perform as expected irrespective of run length or some external factor such as temperature
- **Consistency**, where every printhead and every batch of ink performs as expected

Sustainability is achieved through the implementation of various technologies within printhead and ink design. A number of Fujifilm printheads incorporate ink recirculation that is designed to prevent any pigment settlement, and sweep any bubbles that may form in the ink. Special non-wetting coatings can be applied to printhead nozzle plates in order to minimise ink build up that would, if left unchecked, lead to incorrect jetting behaviour. Fujifilm inkjet inks are designed for extreme sustainability, so pigments are dispersed to a precisely defined particle size using unique Fujifilm technology, and manufacturing systems are designed to maximise system reliability.

Consistency is ensured through a combination of design, where the operating parameters of printheads and inks are precisely defined, and stringent manufacturing process control.

Careful design of inks and printheads together with rigorous testing ensures maximum system reliability.
Fujifilm has a manufacturing philosophy where quality and reliability is built into the products that it makes, and the processes that it uses to make them. Raw material selection and consistency are key parts of the process and Fujifilm has established close business partnerships with its suppliers. These partnerships make sure that raw materials meet an agreed specification and that suppliers operate appropriate quality systems in order to maintain consistency of product and continuity of supply.

Inkjet printheads are produced at the Fujifilm Dimatix facilities in Santa Clara, California and in Lebanon, New Hampshire. The manufacturing operation in Santa Clara includes a state of the art MEMS fabrication foundry that produces the core components of many of Fujifilm Dimatix’ leading printheads.

Water based colorants inks are manufactured by Fujifilm Imaging Colorants in production facilities at Grangemouth, Scotland and New Castle, Delaware. These facilities offer a unique combination of product development and scale up capabilities with significant economies of scale.

UV and hybrid inks are produced at the state of the art manufacturing facility at Fujifilm Speciality Ink Systems operation in Broadstairs, UK. This facility has won the Best Process Plant award in both 2011 and again in 2013. This independent assessment is a testament to the process controls that enable production of Fujifilm’s high quality inkjet products.

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From microscopic...
Fujifilm Samba silicon MEMS printhead: its 2048 nozzles are so small that they are invisible to the naked eye.

...to large scale
Fujifilm inkjet inks are produced in batches of up to several tonnes.
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