Introduction

The concept of inkjet in theory is straightforward. A print head ejects tiny drops of ink onto a substrate. However, in practice implementation of the technology is complex and requires multidisciplinary skills. Reliable operation depends on careful design, implementation, and operation of a complete system where no element is insignificant. Inkjet Technology offers advantages to a wide range of applications. Inkjet is increasing viewed as more than just a printing or marking technique. It can be used to apply coating, to accurately deposit precise amounts of materials, and even to build micro or macro structures. Benefits of inkjet technology include:

- Reduction of manufacturing costs
- Provision of Higher Quality Output
- Conversion of Processes from Analogue to Digital
- Reduction in Inventory
- The new ability to process larger, smaller, or more flexible, fragile or non-flat substrates
- Reduction of waste
- Mass Customization
- Faster Prototyping
- Implementation of just in time manufacturing

Inkjet Technology Explained

All inkjet technologies are based essentially on digitally controlled ejection of drops of fluid from a print head onto the required substrate. However, this can be accomplished by a variety of methods. Inkjet technology is broadly and most typically classified as either continuous or drop-on-demand (DOD), with further sub-classes in each classification. Continuous inkjet technology ejects drops constantly to the substrate or to a collector for re-circulation and reuse. DOD technology ejects drops according the requirements.

Continuous Inkjet (CIJ) Technology: CIJ is a non-contact form of high-speed printing used to apply variable information such as dates, text, batch codes, product names and logos to individual products on the production line. This idea was first patented in 1867, by Lord Kelvin and the first commercial devices (medical strip chart recorders) were introduced in 1951 by Siemens.

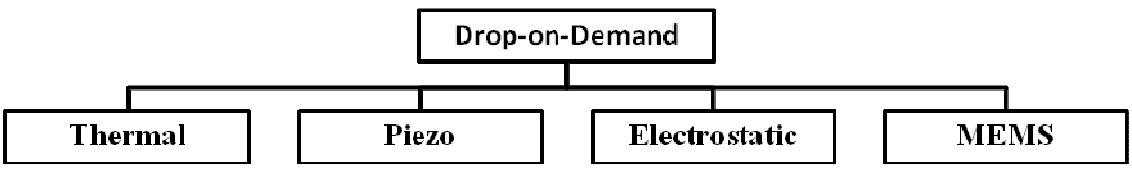
In this technology a high-pressure pump directs liquid ink from a reservoir to microscopic nozzles creating a continuous stream of ink droplets at high frequency (in the range of roughly 50 kHz to 175 kHz) by the way of a vibrating piezoelectric crystal. The ink droplets then are subjected to an electrostatic field to impart a charge, the charged drop then passes through a deflection field, to print on the receptor material (substrate), or allowed to continue undeflected to a collection gutter for re-use. Only a small fraction of the droplets is used to print, the majority being recycled.

Advantages: High speed printing capability, High drop velocity (of the order of 25 m/s) which translates into large distances between the print head and the substrate, which is useful in industrial environment, Ability to use inks based on volatile solvents which allows for rapid drying and increased adhesion on many substrates, Freedom from nozzle clogging as the jet is always in use,

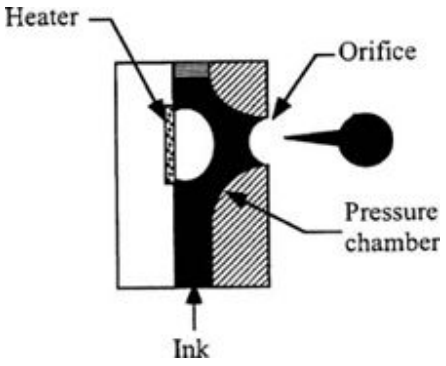
Disadvantages: Relatively Low print resolution, High Maintenance, Environment unfriendly technique due to use of volatile solvent-based fluids, Limitations of printed fluid has to be electrically chargeable.

Major Players: Domino, Imaje, VedioJet, Toxot, Willet, Kodak Versamark

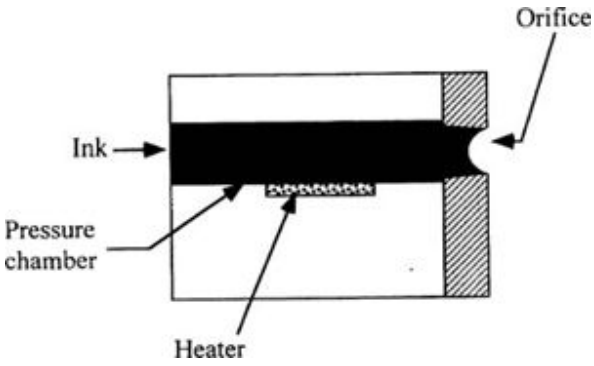
Drop-on-Demand (DOD) Technology: This is a broad classification of inkjet technology where drops are ejected according to the requirement. In general the drops are formed by the creation of a pressure pulse. The method used to generate the pressure pulse is what defines the primary sub-classes with DOD which are as follows:



Thermal Inkjet: The thermal ink-jet method was not the first ink-jet method implemented in a product, but it is the most successfully used in consumer desktop printers and is making inroads in the industry. In this technology, drops are formed by rapidly heating a resistive element in a small chamber containing the ink. The temperature of the resistive element rises to 350^{o}- 400^{o} C, causing a thin film of ink above the heater to vaporize. The vaporization quickly creates a bubble, causing a pressure pulse that forces the drop of ink through the nozzle. Ejection of the drop then leaves a void in the chamber that is subsequently filled by replacement fluid in preparation for creation of the next drop. Depending on its design, a thermal ink-jet can be a roof-shooter with an orifice located on top of the heater, or a side-shooter with an orifice on a side located nearby the heater.



Roof Shooter



Side Shooter

Advantages: This technology offers potential for very small drop sizes and high nozzle density, which leads to compact devices along with lower print head and product costs.

Disadvantages: This technology narrows down the option of ink fluids that can be used. The ink fluid to be suitable for thermal inkjet should be specially designed to vaporize (implying aqueous solution) and must be able to tolerate substantially high local temperatures. A combination of poorly designed fluids & high temperatures can cause a hard coating to form on the resistive element, reducing its efficiency & leading to reduction of print head life. The high temperature can also cause problems if, for example, the functionality of the fluid is damaged due to the high temperature.

Major Players: Canon, HP, Lexmark, Olivetti

Piezo Inkjet: Piezoelectric inkjet is currently the technology of choice for most emerging industrial application. In this technology, a piezo crystal undergoes distortion when an electric field is applied, and this distortion is used to mechanically create a pressure pulse that causes a drop to be ejected from the nozzle. There are many variations of piezo inkjet architectures including tube, egde, face, moving wall, and piston.
Advantages: Allows maximum ink development freedom amongst all the inkjet technologies, Long head life.
Disadvantages: Higher cost for print heads and associated hardware, limiting cost effective integration in low end products.
Major Players: XAAR, Trident, Seiko-Epson, Konica Minolta, Hitachi Ricoh, Fujifilm Dimatrix

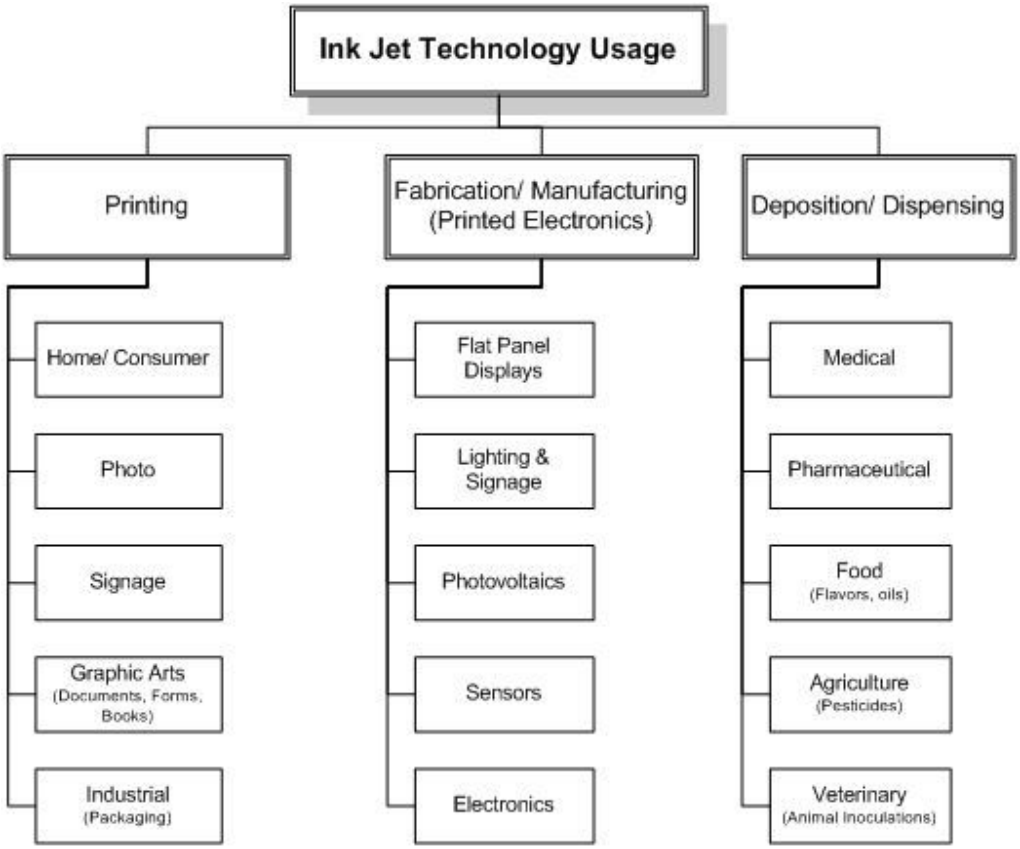
Electrostatic Inkjet: Electrostatic inkjet is characterized by drops being drawn from an orifice under the influence of an electrostatic field. This field, acting between an electrode and the orifice, attracts free charges within the ink to its surface in such a way that a drop is produced when the electrostatic forces pull exceeds the surface tension of the ink. As this technique relies on the attraction of free charges, the ink is required to be conductive.
Advantages: Higher achievable resolutions than piezo inkjet are possible, Very small drops can be formed while still using pigments, as the size of the drop is controlled by the voltage on an ejection point and the properties of the particles, rather than by the size of the nozzle, High optical density images are possible due to the high concentration of ink fluid in the ejected drops.
Disadvantages: Only conductive fluids can be used, high cost of implementation of the technology.
Major Players: TTP, NEC, Tokyo Electric, Mathushita

MEMS Inkjet: This technology gets its name Micro-Electro Mechanical Systems (MEMS) fabrication techniques, which are currently used for integrated circuit production and have been adapted to manufacture inkjet heads. MEMS is proving to be a boon in creating nozzles, holes, manifolds and channel structures in inkjet head design. MEMS inkjet heads can be fabricated using modified semiconductor fabrication technology, laser ablation, photolithography, molding

and plating, wet etching and dry etching, electro discharge machining (EDM), and other technologies capable of manufacturing very small devices. MEMS DOD print heads are invariably still, based on either piezo or thermal inkjet technology.

Advantages: The scale of MEMS is such that it permits larger and denser arrays of smaller ink orifices, increasing print resolution and MEMS inkjet heads work on the concept of single pass inkjet printing thus increasing the printing speed.

Disadvantages: At the moment, the type of ink fluid than can be used is restricted to aqueous, With a multitude of nozzles present, there is a need to develop foolproof unclogging systems and mechanism to detect/correct faulty nozzles, Initial high cost of implementation till it become a widely used technology.



References

1) The Chemistry of Inkjet Inks, Shlomo Magdassi.
2) Hue P. Le., (1998), Progress and Trends in Ink-jet Printing Technology, Journal of Imaging Science and Technology 42(1): 49–62, Le Technologies, Inc., Beaverton, Oregon
3) Burton J., Single Pass Inkjet Explodes – MEMS the Word