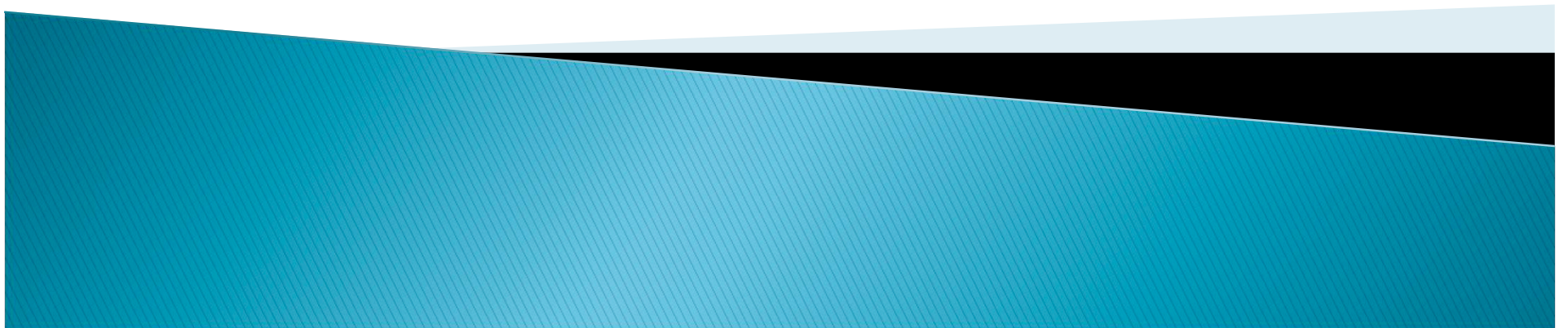


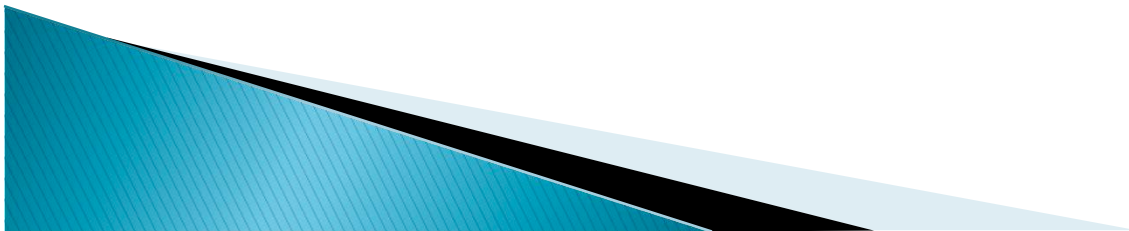
Inkjet Technology: Progress, Trends & Business Opportunities

Graphics Canada, November 2011
Vince Cahill, VCE Solutions



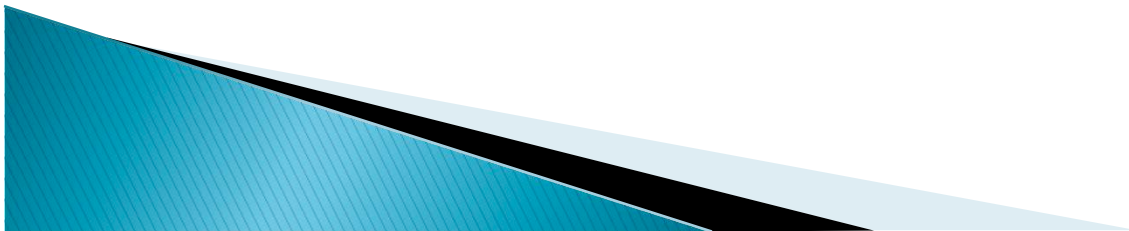
Vince Cahill

- ▶ Printer for over 20 years
- ▶ Consultant and journalist for over 17 years
- ▶ Former CEO of Datametrics, owner of the Colorworks, Industrial Printing Solutions, Specialty Materials, Newhill Technologies
- ▶ President of VCE Solutions, Digital Print & Fabrication Technology and Market Consultancy 717-762-9520
- ▶ vince@vcesolutions.com



Agenda

- ▶ Inkjet Technology
- ▶ IJ Progress: Technologies
- ▶ IJ Progress: Markets & Applications
 - Graphics
 - Textile
 - Commercial
 - Deposition
- ▶ IJT Trends
- ▶ IJT Business Opportunities
 - Coming technologies & strategies for benefiting from them



Inkjet Beginnings

- ▶ 1749 – Jean–Antoine Nollet manipulating a stream of drops with electricity
- ▶ 1856 – Joseph Plateau – On liquid jets from nozzles
- ▶ 1858/1867 – William Thomson (Lord Kelvin) develops first inkjet like recording device for recording the signals of the Atlantic Cable
- ▶ 1878 – Lord Rayleigh *Instability of jets*
- ▶ 1951 – Elmqvist of Siemens–Elema patented the first practical CIJ device (US Patent 2,566,433)

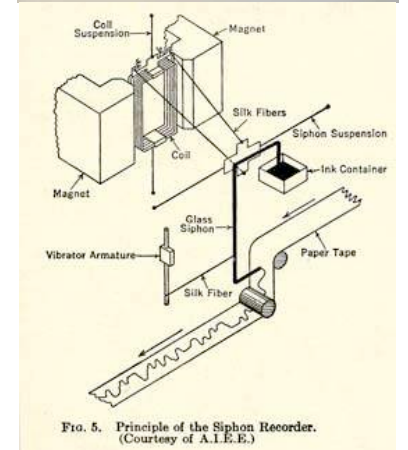
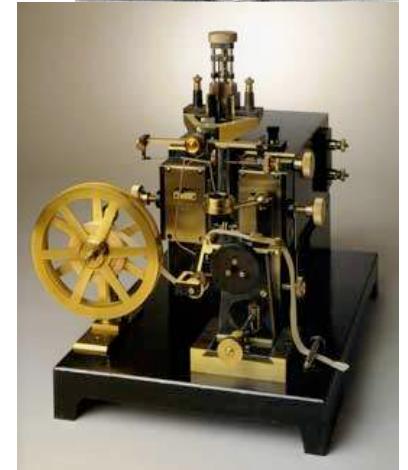


Image sources: <http://commons.wikimedia.org>; <http://atlantic-cable.com>

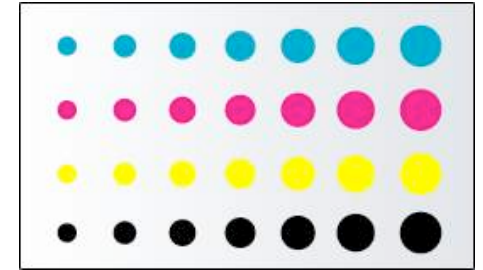
Inkjet Early Progress

- ▶ 1960s – Sweet (US Patent 3,596,275) CIJ – A.B. Dick Videojet 9600
- ▶ Late 1960s to early 1970s – Electrostatic pull inkjets from Teletype, Casio, and Paillard
- ▶ 1965 – First Thermal Inkjet (US Patent 3,179,042)
- ▶ 1972 – Zoltan of Clevite Co. (US Patent 3,683,212), Squeeze mode PIJ
- ▶ 1973 – Stemme of Chalmers University (US Patent 3,747,120), Bend mode PIJ
- ▶ 1984 – S. Howkins of Exxon (US Patent 4,459,601), Push (piston) mode PIJ
- ▶ 1984 – Fischbeck (US Patent 4,584,590), Shear mode PIJ
- ▶ 1977 – TIJ rediscovered by Ichiro Endo of Canon
- ▶ 1984 – HP Thinkjet

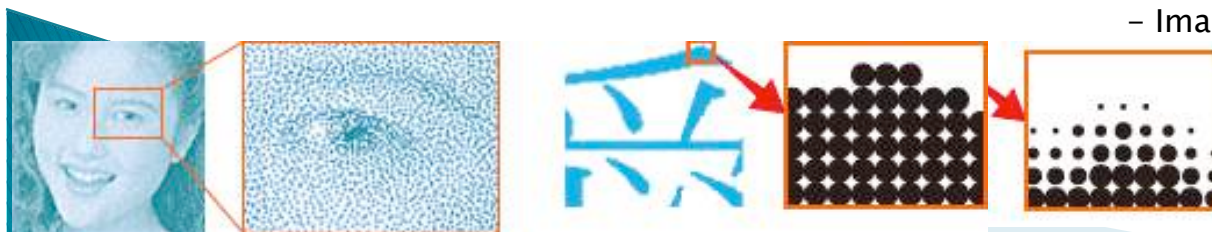
1960s–1970s

1970s–1980s

Inkjet Evolving



- ▶ From binary to grayscale
- ▶ From macro to MEMS micro machining
- ▶ From scanning heads to single pass
- ▶ From fitting application to match inkjet technology to designing inkjet technology to match application requirements
- ▶ From sub boiling temperature operation to also high temperature performance
- ▶ Inkjet moving from 2D graphics to 3D fabrication



- Image with grayscale technology
300dpi 8levels

Elements of Inkjet Technology

- ▶ **Print heads**
- ▶ **Firmware, driver, RIP and image generation software**
- ▶ **Print controller electronics**
- ▶ **Print head monitoring & maintenance**
- ▶ **Print head &/or substrate movement**
- ▶ **Substrate transport & handling**
- ▶ **Ink or fluid**
- ▶ **Ink delivery**
- ▶ **Color control**
- ▶ **Pre-coating to make substrate print receptive**
- ▶ **Curing, fixing & drying**
- ▶ **Integration**
- ▶ **Tailoring and tuning components to meet needs**



Inkjet Print Head Technologies

Drop-on-Demand (DOD)

Continuous

Piezo (PIJ)

Fujifilm Dimatix

Sharp

Domino

Brother

Videojet Marsh

Epson

Ricoh

Trident

Kyocera

HP Aprion, X2

Xaar

Toshiba-tec

Panasonic

Seiko II

Samsung

Konica Minolta

Xerox (Tektronix)

PicoJet/NextJet

Thermal (TIJ)

Canon

HP

Lexmark

Kodak

Olivetti

Xerox

Silverbrook Memjet

Electrostatic

TTP-ToneJet

NEC

Tokyo Electric

Matsushita

ValveJet

Milliken

Zimmer

Foxjet

Domino

Videojet Printos

Image Crayon

Loveshaw

Kortho

Binary

Stork

Scitex Iris

Siemens

Domino

Kodak Versamark

Multi-level

VideoJet Danaher

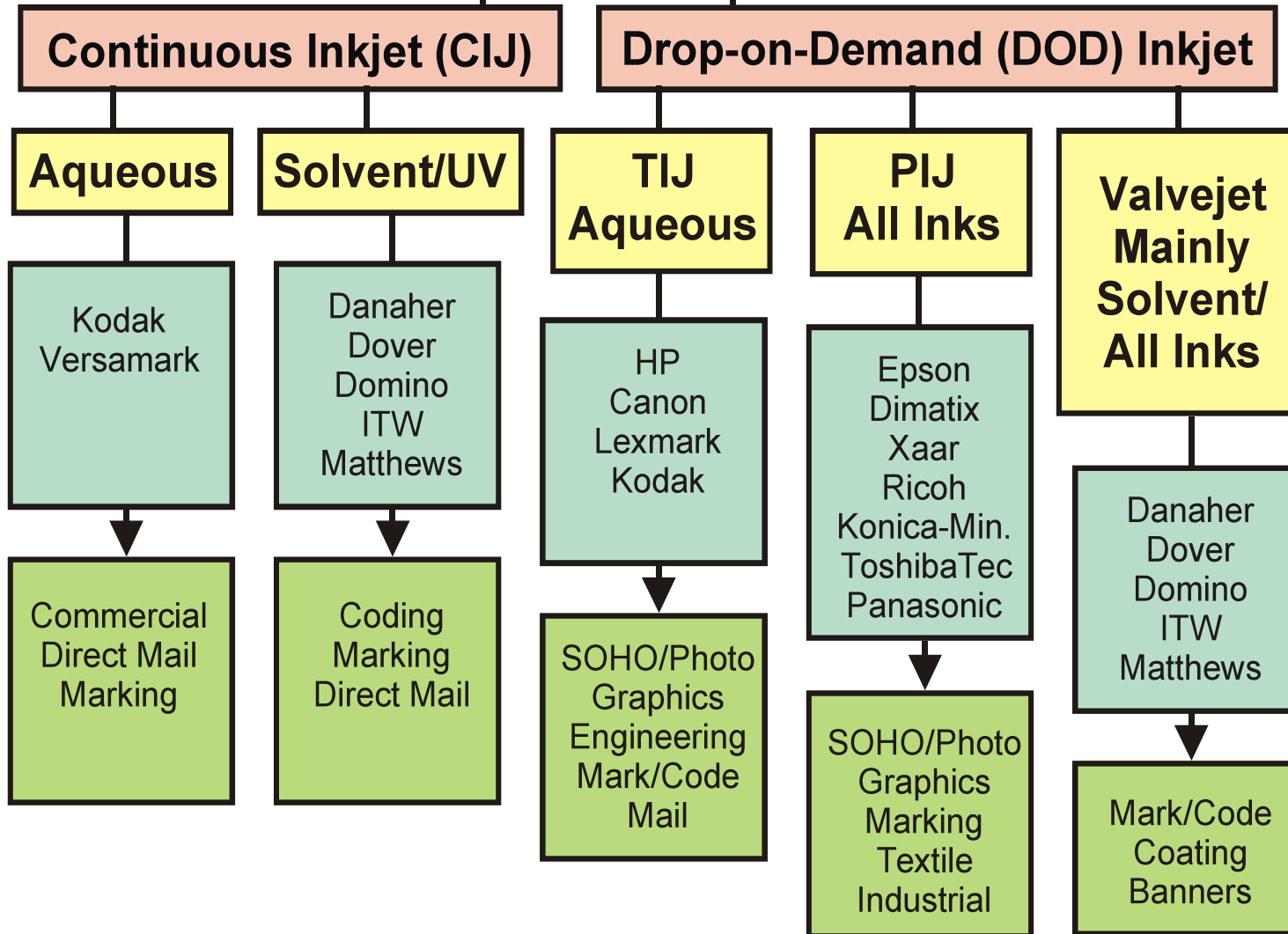
Image Dover

Jemtex

Linx

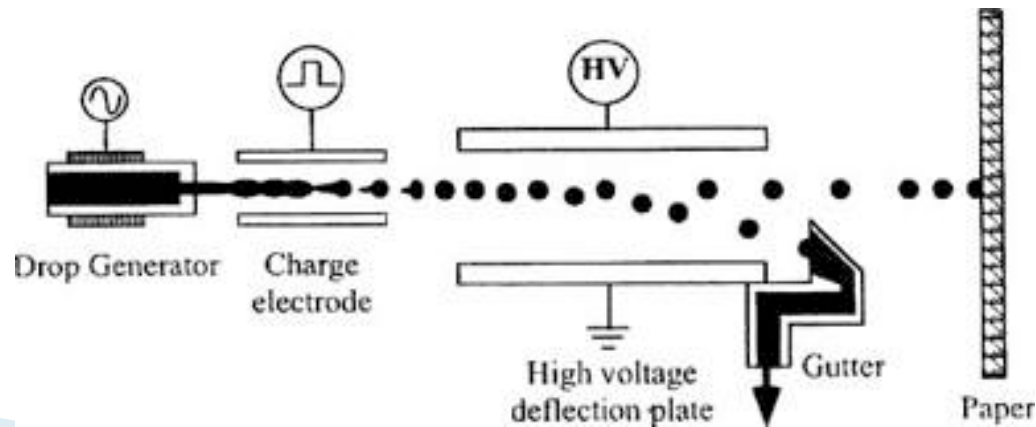
Willet

Inkjet Technologies



Binary Continuous Inkjet

- ▶ Piezo ceramic actuators pump fluid that charge can carry a charge
- ▶ Droplets that are to print do not receive a charge as they pass through the charge electrode, those that are not to print do
- ▶ As drops enter deflection plate, charged drops that are not to print are deflected into gutter to recycle while uncharged drops print
- ▶ Similar method: Hertz CIJ – Iris, Stork



Binary Continuous Inkjet

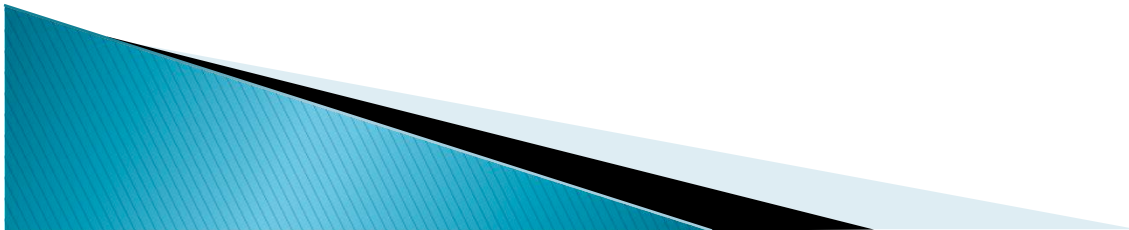


Kodak Stream

- ▶ Kodak Stream Prosper
 - Binary CIJ with thermal stimulation for drop generation
 - 200 mpm
 - Up to 175 lpi
 - Prosper print quality equals that of lithography

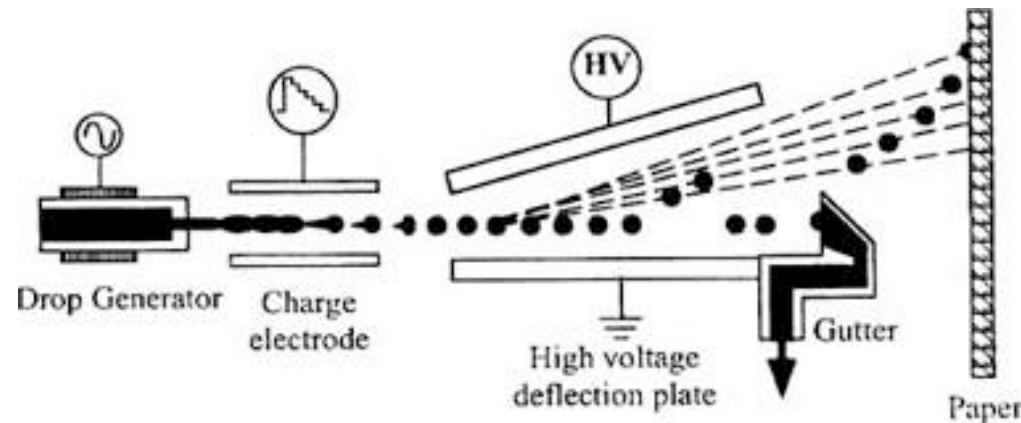


KODAK PROSPER 1000 Press

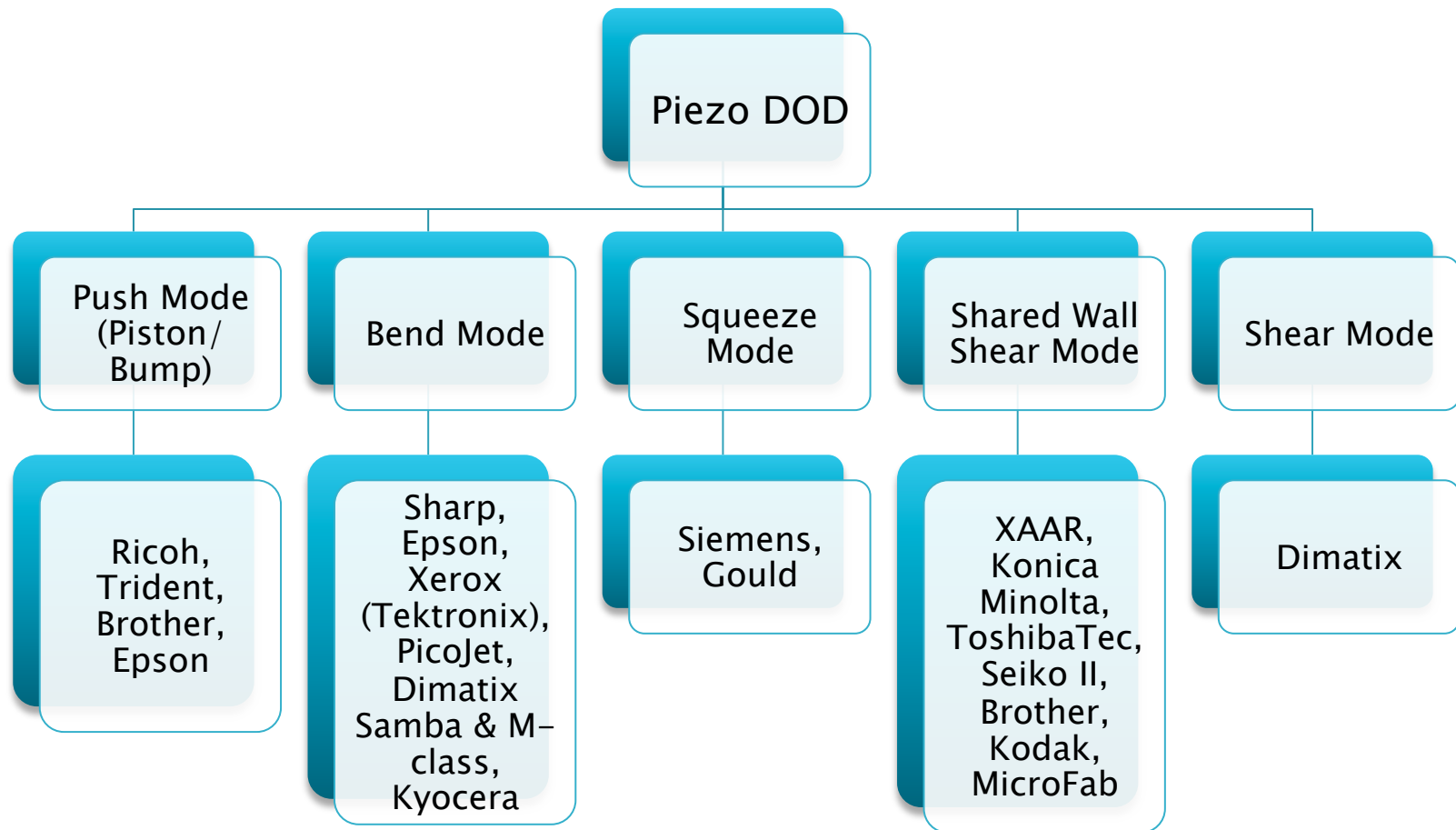


Multilevel Continuous Inkjet

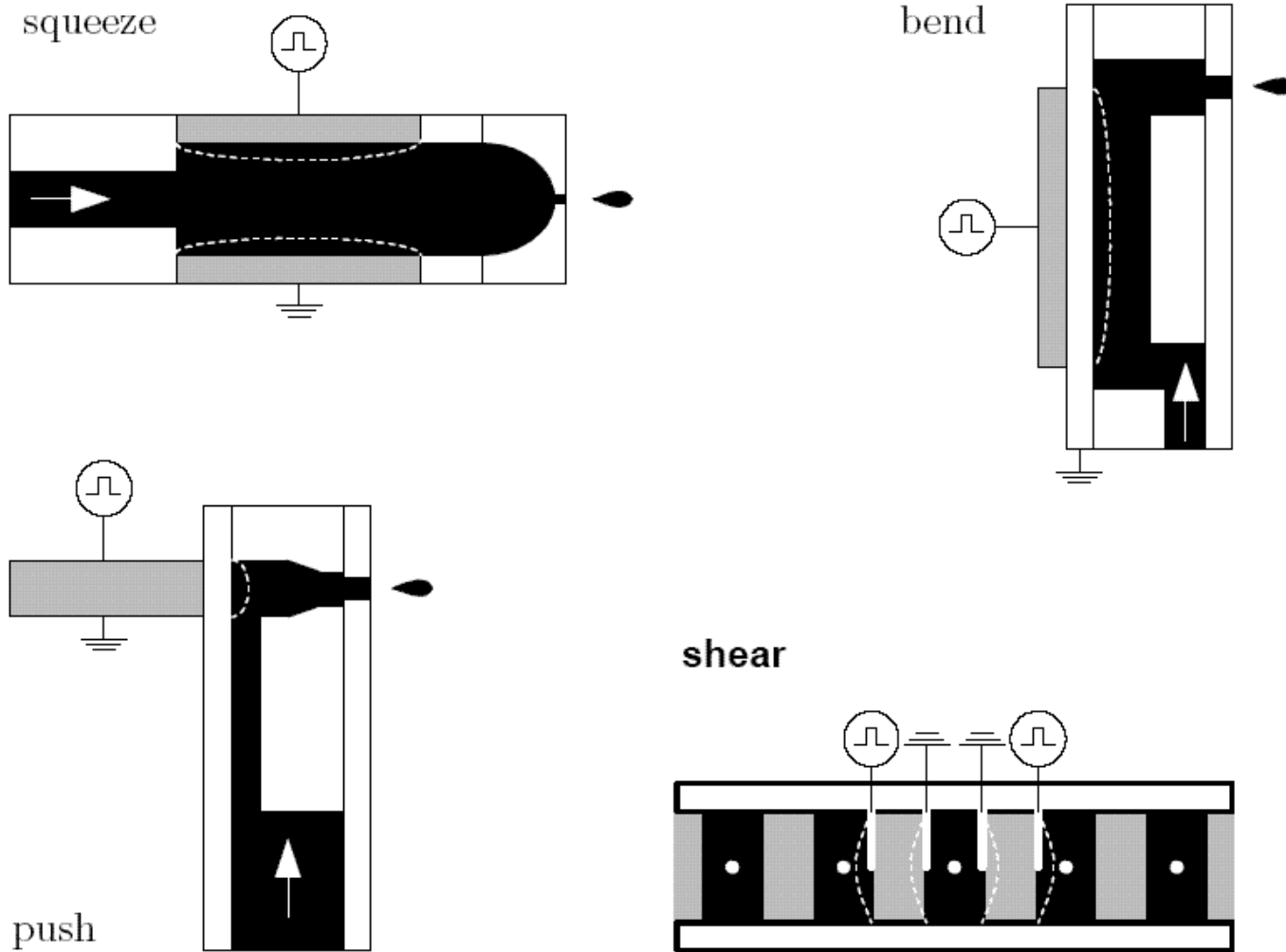
- ▶ Piezo ceramic actuators pump fluid that charge can carry a charge
- ▶ Drops that are to print receive an amount of charge depending on where it is to print
- ▶ As drops enter deflection plate, uncharged drops that are not to print enter the recycle gutter, while charged drops are directed to locations on the substrate matching receive their charged level



Piezo Drop On Demand Modes

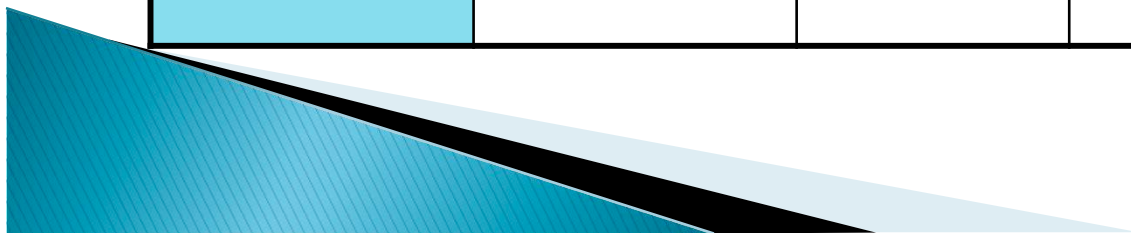


Piezo Inkjet Modes



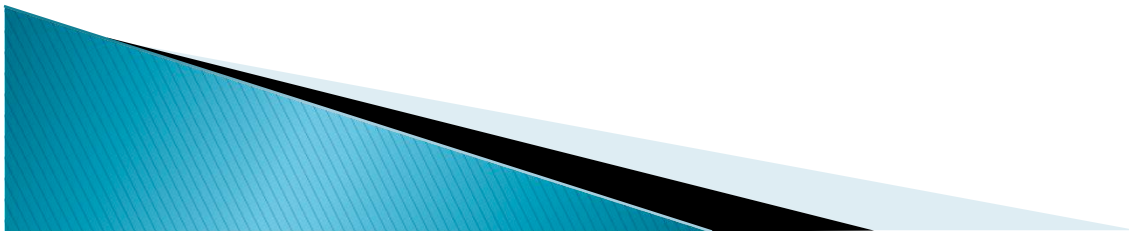
Diagrams source: Herman Wijshoff, *Structure and fluid-dynamics in piezo inkjet printheads*, (2008)

	Frequency Range kHz	Viscosity Range cP	Ink Type	Drop Size pl (nl)
CIJ	50-500	3-6	Aqueous, Solvent, Rad-cure	2-6
LD PIJ	4-10	2-6	Aqueous, Eco/Bio, Solvent	2-6
HD PIJ	4.8-60	6-30 (200)	Aqueous, Oil, Rad-cure, Phase change, Bio-Eco, Solvent	3-90
TIJ	1.5-50	2-5	Aqueous, (UV)	1-220
Valve J	<2	1-350 (2000)	Aqueous, Oil, Rad-cure, Phase change, Bio-Eco, Solvent	(1-150)



Print Heads & Applications

- ▶ **Piezo Drop-on-Demand (DOD) Inkjet (PIJ):** Graphics, textile, commercial printing, industrial, digital fabrication, biomedical
- ▶ **Thermal DOD Inkjet (TIJ):** Desktop, graphics, commercial, biomedical
- ▶ **Electrostatic DOD:** Beverage cans
- ▶ **Valve Jet:** Carpet printing, coating, marking & coding
- ▶ **Continuous Inkjet (CIJ):** proofing, marking & coding, textile

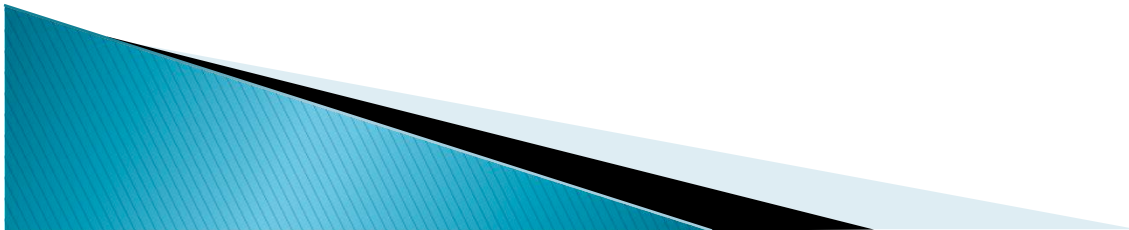
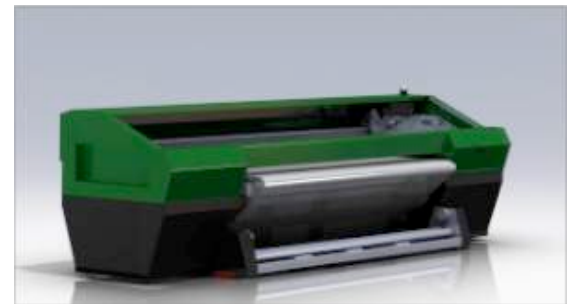
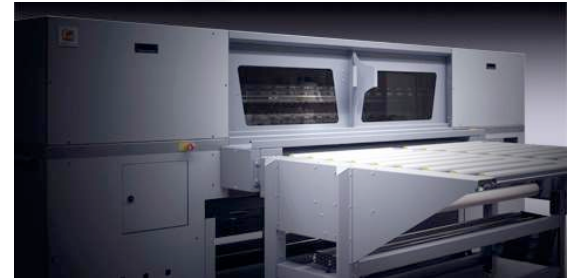


Inkjet Graphics Applications

- ▶ Coding & Marking
- ▶ Carpeting
- ▶ Office Inkjet
- ▶ Addressing Direct Mail
- ▶ Proofing
- ▶ CAD
- ▶ **Wide Format Graphics, Billboards & Signage**
- ▶ **Textiles**
- ▶ Wall Covering
- ▶ Floor Covering
- ▶ Ceramics
- ▶ Photo Finishing
- ▶ **Plastic Cards, Labels**
- ▶ Food Decoration
- ▶ **Packaging**
- ▶ **Commercial Printing**

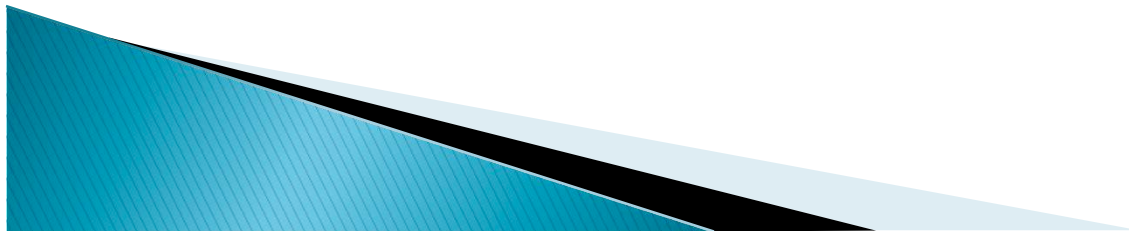
Recent Wide Format/Packaging

- ▶ Inca Digital Onset S40 (S70, S20)
 - 470 m²/hr rigid stock
- ▶ Durst Omega 1
 - Lower cost, grayscale, Ricoh Gen4
- ▶ Novus Imaging Synergia H/UV & Synergia H/AQ
 - Dimatix Q-class & aqueous epoxy
- ▶ HP & Sepiax Latex
- ▶ LED UV Curing



Recent IJ Introductions: Textile

- ▶ Durst Kappa (Ricoh Gen4)
- ▶ MS LaRio (Kyocera KJ4B)
- ▶ Konica Minolta Nassenger Pro 1000 (KM 1024 – 4 lines of 256 nozzles)
- ▶ SPG Prints (Stork) Sphene & inks (Kyocera KJ4B)
- ▶ La Meccanica (Kyocera KJ4B)
- ▶ Kornit Allegro (Dimatix Nova AAA)
- ▶ D-gen Teleios Grande (Ricoh Gen4L)
- ▶ Shima Seiki new SIP flatbed (Ricoh Gen 4L)
- ▶ Anajet mPower (Ricoh Gen4)



Recent Commercial IJ



- ▶ HP Web Press (HP Edgeline TIJ heads)
 - Up to 30 inch (762mm) web width
 - 400 feet (122 meters) per minute speed
 - HP Pigment Inks + Bonding Agent
- ▶ Océ JetStream – Miyakoshi (Kyocera KJ4 PIJ)
- ▶ Fuji Xerox 2800 – 200 m/min
- ▶ Fujifilm J Press (Dimatix Samba PIJ)
- ▶ Kodak Prosper (Kodak Stream CIJ)

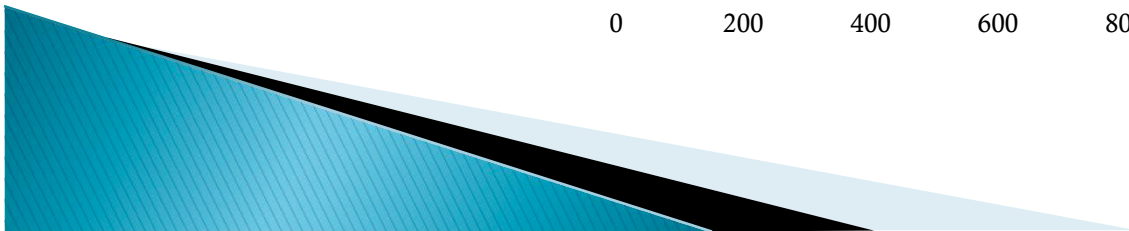
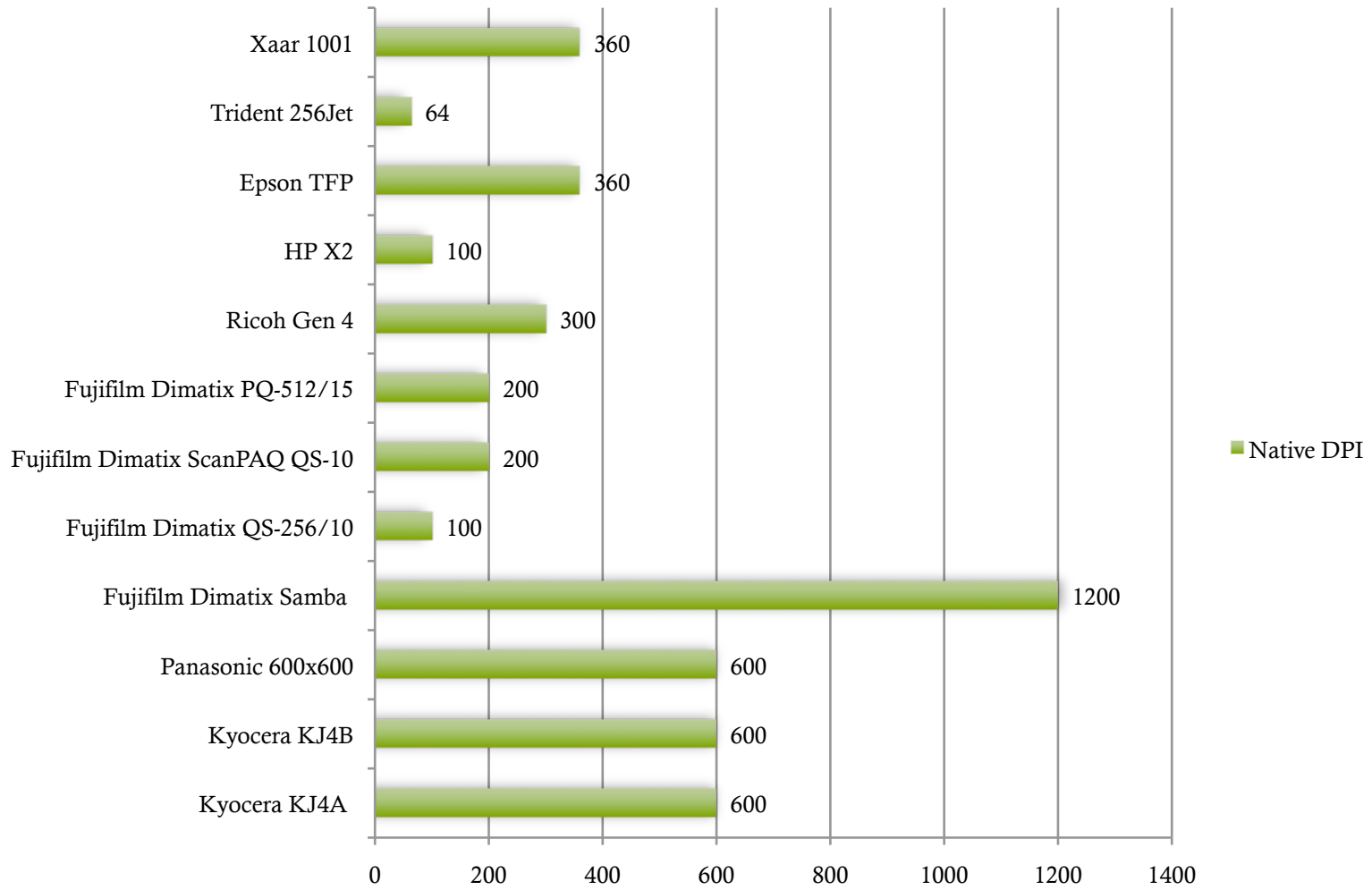


Analog Throughput

Print Technology	Format Size	Throughput m/min	Applications
Litho Offset Duplicator	30.5x45.7cm (12"x18")	Up to 100	Business forms, labels, postcards, letterhead
Litho Offset Web Press	43cm or 86cm (17" or 34"rolls)	Up to 900	Newspapers, magazines, books
Rotogravure	60cm to 120cm typically	120	packaging, magazines, catalogs, pressure sensitive labels, gift wrapping, wallpaper, plastic laminates, printed upholstery, imitation wood grain finishes, vinyl flooring
Flexography	60cm typical to 200cm	Up to 100	Plastic packaging, gift wrap, wall-covering, magazines, newspaper inserts, paperback books, telephone directories, business forms

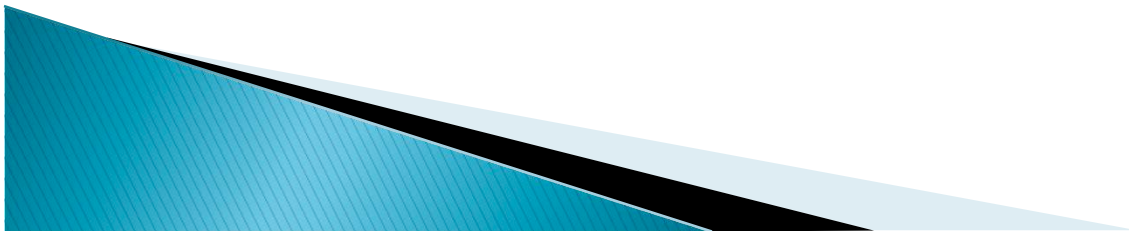
PIJ Heads Fluid Tolerance

Print Head Model	Oil	Water	Solvent	UV-cure	Max cP Viscosity
Kyocera KJ4A	X	X	0	0	8
Kyocera KJ4B	X	X	0	X	6
Panasonic 600x600	X	X	0	X	10
Fujifilm Dimatix Samba	X	X	0	X	8
Fujifilm Dimatix QS-256/10	X	X	X	X	20
Fujifilm Dimatix ScanPAQ QS-10	X	X	X	X	20
Fujifilm Dimatix PQ-512/15	X	0	X	X	14
Ricoh Gen 4	X	X	X	X	12
HP X2	X	0	0	X	15
Epson TFP	X	X	x/0	0	6
Trident 256Jet	X	X	X	X	20-30
Xaar 1001	X	0	X	X	50

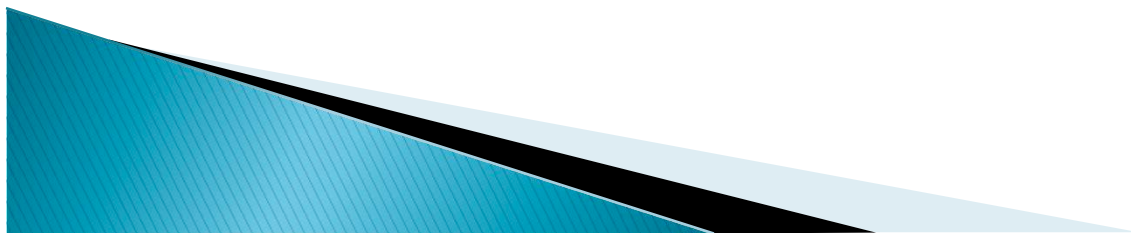
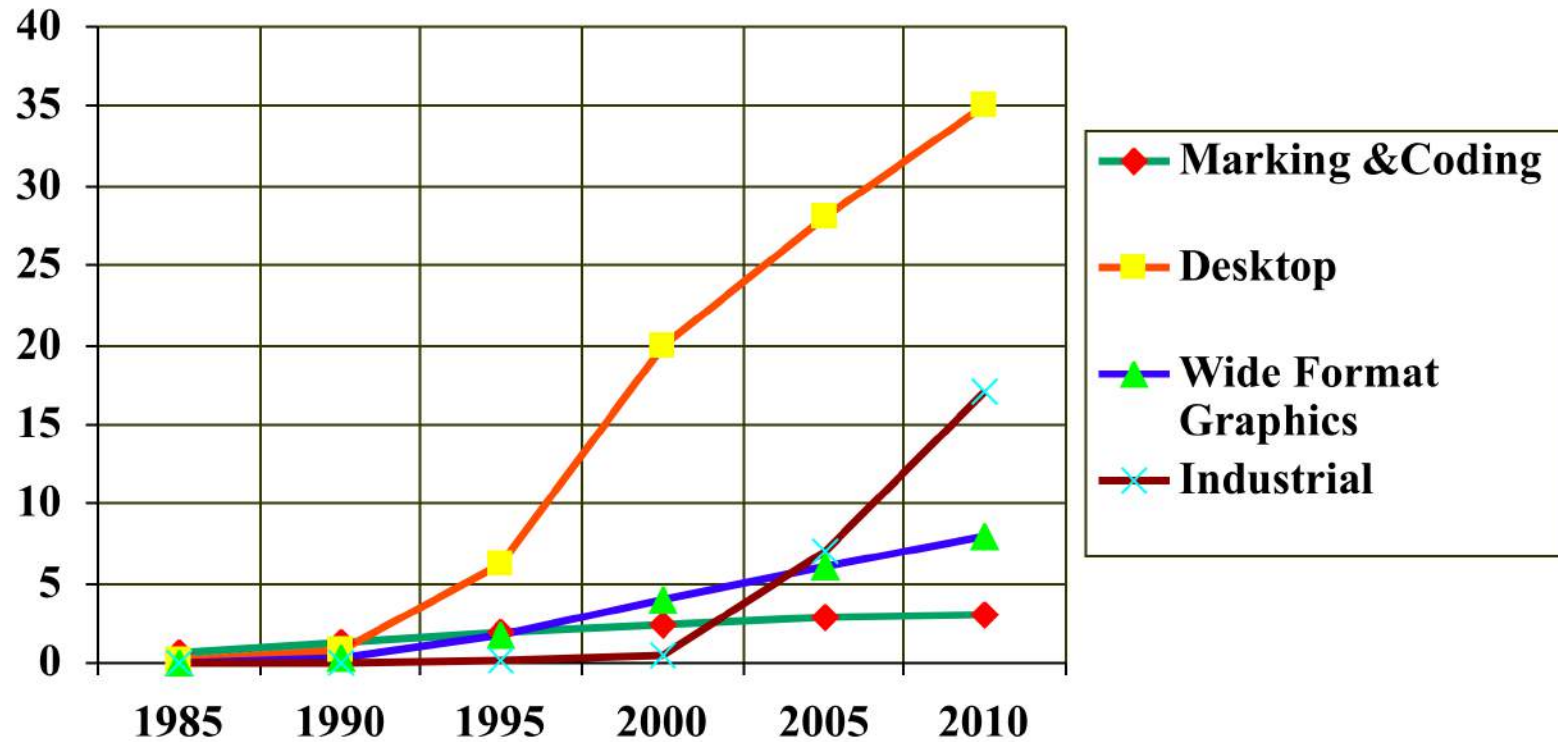


Commercial & Wide Format

- ▶ Roland DG says the global market for wide-format digital inkjet printing is estimated to be worth a staggering \$80bn per year, and yet commercial printers occupy less than 5 per cent of this sector
- ▶ Few barriers to entry; a commercial printer producing wide format prints is really no different to producing any other form of colour printing,

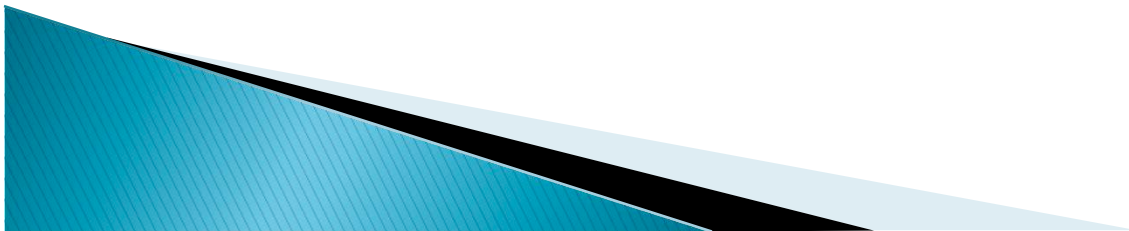


Worldwide Inkjet Markets

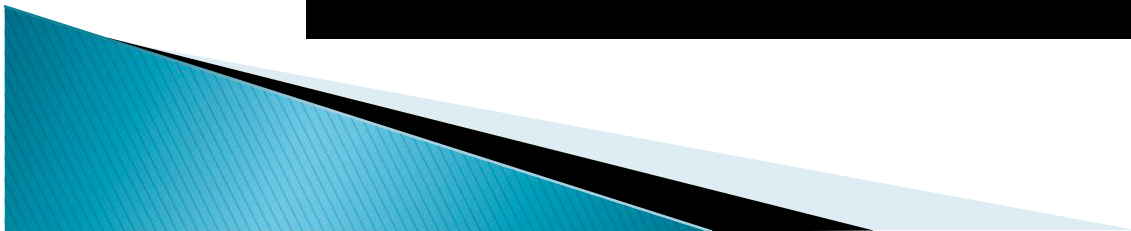
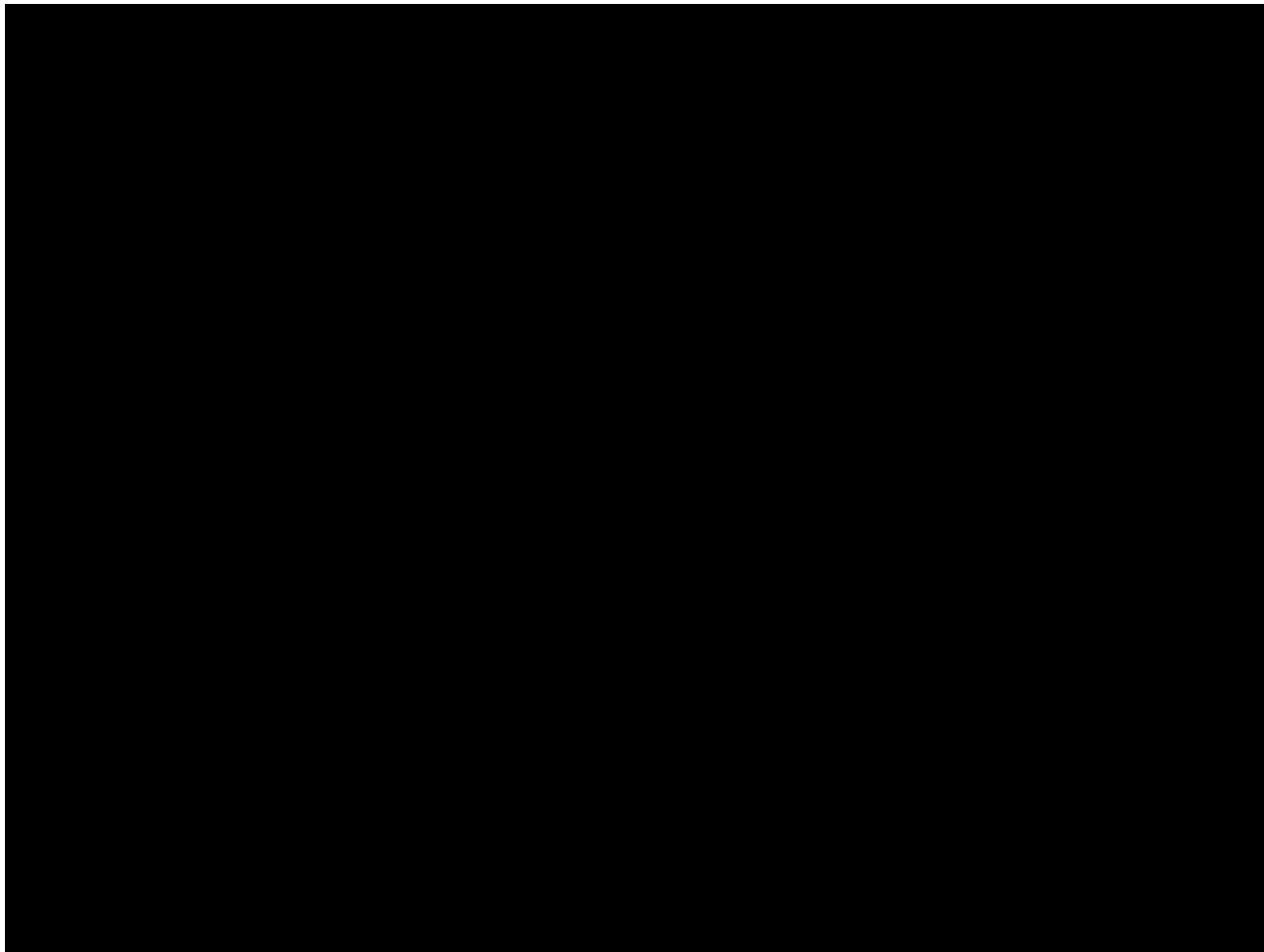


Inkjet Deposition Applications

- ▶ Electronics
- ▶ Photovoltaics
- ▶ Displays
- ▶ 3D Fabrication
- ▶ Chemical Formulation
- ▶ Optical
- ▶ Biomedical



Fujifilm Dimatix Inkjet Deposition



Dimatix Deposition Tools

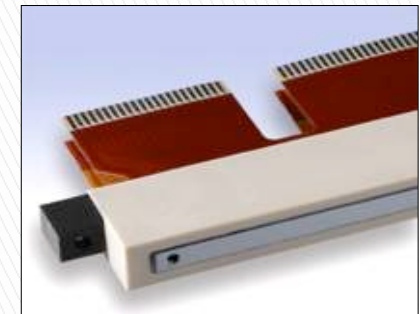
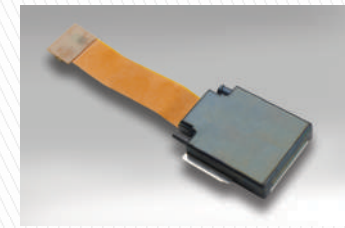
- ▶ DMP-2800
- ▶ DMP-3000
- ▶ DMP-5000
- ▶ DMP-5005



Deposition Printers

Endura

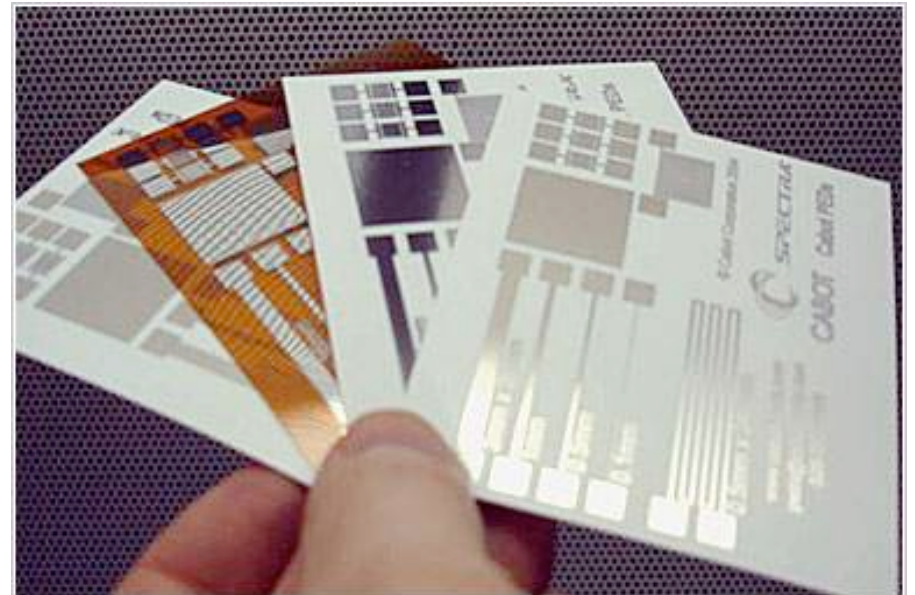
- ▶ DMC-11601
- ▶ DMC-11610
- ▶ D-128/1 DPN
- ▶ D-128/10 DPN
- ▶ SX3
- ▶ SE-DPN
- ▶ SE3



Deposition Printheads

Deposition Applications: Electronics

- ▶ Flex Circuits
- ▶ RFID
- ▶ PCB Photomasks
- ▶ Wearable Electronics
- ▶ Solar
- ▶ Fuel Cells
- ▶ Batteries



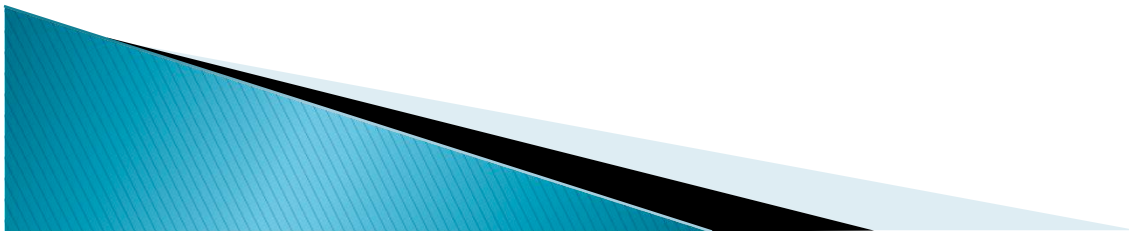
Printed Electronics Opportunity

- ▶ Printed electronics offers the advantages low fabrication cost & simple fabrication
- ▶ Applications with potential include lighting, RFID tags, sensors, and batteries.
- ▶ The global printed electronics market is expected to reach \$24.25 billion by 2015
- ▶ Need for miniaturization & portability for electronics serving telecommunications, packaging, automotive, medicine, military & end-user consumer markets is driving the demand for flexible electronic products
- ▶ Power generation and conservation needs are driving the development of photovoltaics and printable lighting.
- ▶ Asia-Pacific accounts for 42.5% in the printed electronics market in 2010 & is expected to be the fastest growing market at a CAGR of 40.8% from 2010 to 2015.
- ▶ Industry players include NovaCentrix (U.S.), Conductive Inkjet Technology (UK), E Ink Holdings (Taiwan), NTERA (U.S.), Vorbeck Materials (Switzerland), and DuPont (U.S.)



Displays

- ▶ Flat Panel Displays – saturated
- ▶ PLED – high roller players
- ▶ LCD – commodity
- ▶ Color Filters – commodity
- ▶ Display Backplanes
- ▶ Flexible Displays – opportunity
- ▶ Touch Panels – opportunity

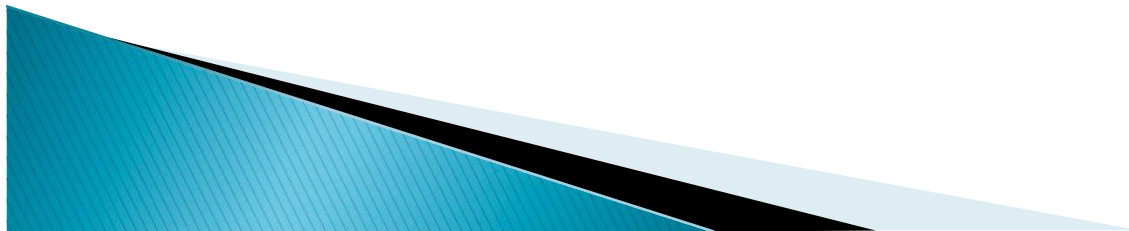


Biomedical

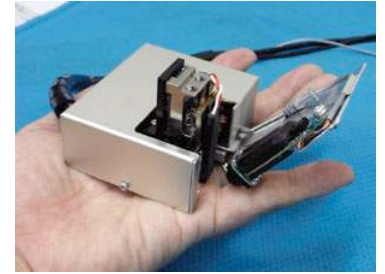


Photo source: [Science](#) | August 3, 2010

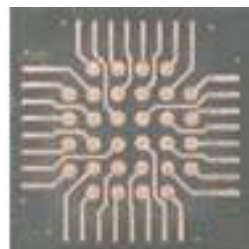
- ▶ Transdermal medicine delivery
 - Small molecule drugs, such as nicotine & progesterone
- ▶ Transdermal micro-needles
 - Solid micro-needles are coated with the larger molecule drug to be delivered like Vitamin B
 - Needles can be metal, silicon, fiberglass, polymer
 - Hollow micro-needles deliver drugs using a simple pump or are used to remove fluids such as glucose for testing
 - HP TIJ inkjet & Crospon of Galway, Ireland 2007
 - Dissolvable needles



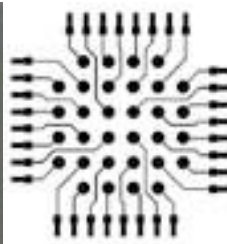
AIST Super-fine Inkjet



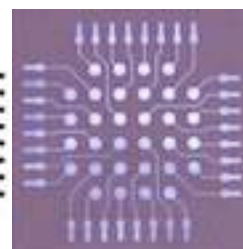
- ▶ SIJ Technology Japan
- ▶ Jet particles < 20nm
- ▶ Super-fine metal particles melt at much lower temp
- ▶ Electro-conductive polymers, functional ceramics, carbon nanotubes, super fine wire patterning



Conventional IJ



Cad Drawing



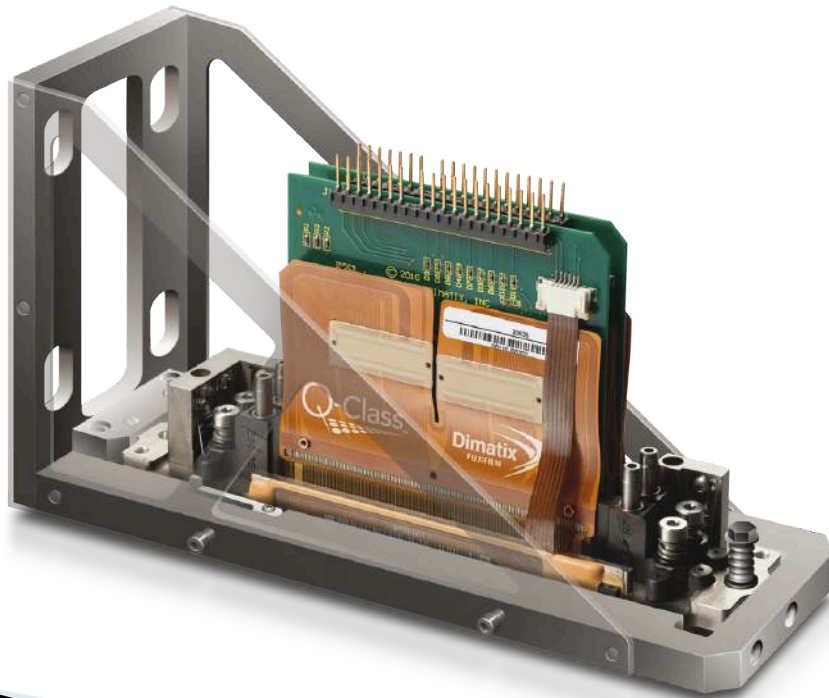
Super-fine IJ

Electrohydrodynamic Jet (E-Jet)

- ▶ New electrostatic based ink-jet print system
- ▶ E-Jet is controlled by changing the voltage potential between the nozzle and the substrate.
- ▶ For printing submicron dots, lines & patterns
- ▶ Disperses wide range of functional fluids including polymers, nanoparticle suspensions, and biomaterials
- ▶ Resolution approaching 25 nm vs. 1–2 microns for PIJ & TIJ
- ▶ Can print charged liquids as patterns/templates with polarities selectively controlled by electric field directions



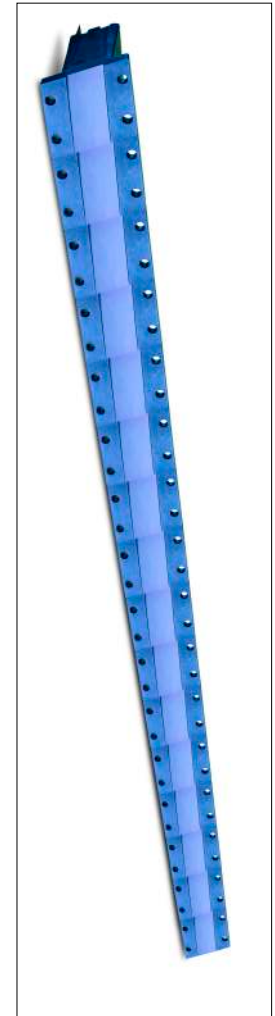
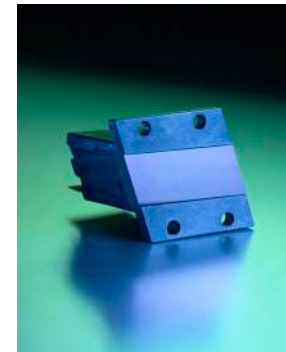
Fujifilm Dimatix 4-color Polaris



- ▶ 4-color shear mode PIJ
- ▶ 15 pl drop to 30 pl with VersaDrop binary
- ▶ 8 to 20 centipoise viscosity
- ▶ 114 addressable nozzle per color
- ▶ 100 dpi native
- ▶ Uses UV-cure, solvent or aqueous inks
- ▶ Built in heater
- ▶ Operates up to 60°C
- ▶ Field repair or replacement without special tools

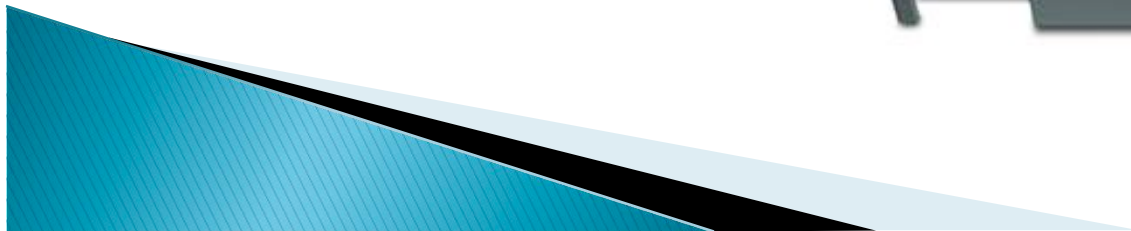
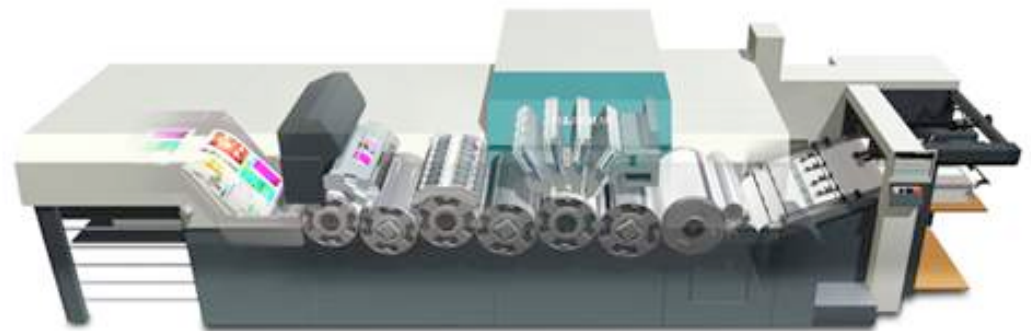
Fujifilm Dimatix Samba

- ▶ MEMS construction
- ▶ VersaDrop multi-pulsing
- ▶ Drop sizes: 0.1, 1.0, 2.0 pl
- ▶ Meniscus replenishment
- ▶ Ink recirculation
- ▶ Frequency: 45 to 100kHz
- ▶ 2048 nozzles per module
- ▶ 1200 dpi native
- ▶ Designed for large arrays



Fujifilm J-Press 720

- ▶ Samba 1200 dpi native heads
- ▶ 4 dot grayscale 2 pl primary drop
- ▶ 2,700 (max) 28.3" x 20.5" four-up size sheets per hour, or 10,800 8.5" x 11" pages per hour
- ▶ Prints offset quality with inline stock coating
- ▶ Single pass



Ricoh Gen4 & Gen4L

- ▶ Push mode PIJ, dual port
- ▶ Aqueous, oil, solvent and UV-cure
- ▶ 10–12cP at operating temp.
- ▶ Gen4: 7, 14, 21 pl
- ▶ Gen4L: 15, 30, 45/27, 54 pl
- ▶ 384 nozzles (2 rows of 192 nozzles offset $\frac{1}{2}$ pitch)
- ▶ 300dpi native, 480m/min
- ▶ 32.5mm Print swath
- ▶ 30kHz binary, 20 kHz grayscale
- ▶ Primarily stainless steel



Image source: Ricoh

Inkjet Printers Using Gen 4

- ▶ Mimaki UJF 3042 & TX 400-1800
- ▶ Lawson Express Jet
- ▶ Gandy Digital Pred8tor
- ▶ Digitex Gunsjet SR,SF & UF series
- ▶ Agfa Graphics Jeti 1224 UV & 3020
- ▶ D-gen Teleios Grande (Gen 4L)
- ▶ Shima Seiki SIP (Gen 4L)
- ▶ Durst Kappa 180



Mimaki UJF 3042



Tx400-1800B
Belt carrier system

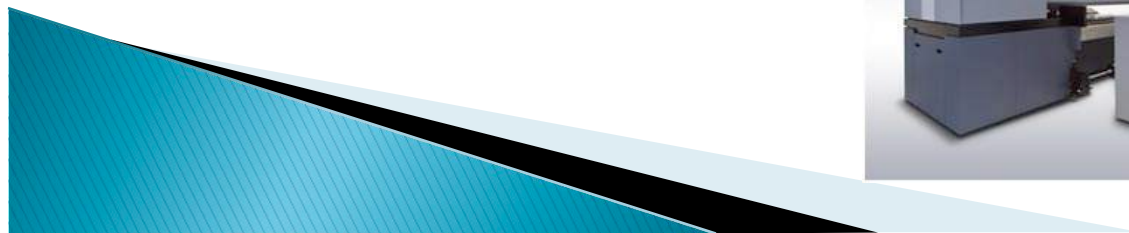


Lawson Express Jet ASI

d-gen Teleios Grande



Durst Kappa 180



Kyocera KJ4

- ▶ Compact piezo actuator with high frequency 30kHz & 40kHz versions
- ▶ 2,656 nozzles
- ▶ 4.25-inch print width
- ▶ KJ4B uses aqueous
- ▶ KJ4A for UV-cure inks & fluids



Single pass:

- 600x360dpi (330m/min at 40kHz)
- 600x600dpi (200m/min at 40kHz)
- 1200x1200dpi (150m/min at 60kHz)

Xennia

- ▶ Ultramarine single-pass ceramic printer
 - Oil-based ceramic ink
 - Xaar 1001 with 8 gray levels and recirculation
 - 4-color standard
- ▶ Sapphire scanning head single-pass ceramic printer
 - XenInx Diamond UV cure inks
 - Up to 6-color



Matching Heads to Applications

one type does not fit all applications

- ▶ Single-pass throughput
- ▶ Firing frequency
- ▶ Fluid firing viscosity range
- ▶ Fluids tolerated
- ▶ Drop velocity
- ▶ Native dpi
- ▶ Crosstalk
- ▶ Print line length
- ▶ Fluid to substrate, treatments
- ▶ Nozzle diameter
- ▶ Nozzle pitch
- ▶ Drop size
- ▶ Drop firing straightness
- ▶ Grayscale capability
- ▶ Drop throw distance
- ▶ Heater
- ▶ Maximum operating temperature



Trends

Print Head & System

- ▶ Higher drop frequency
- ▶ MEMS construction
- ▶ Single-pass
- ▶ Aqueous tolerant
- ▶ Multiple head type systems
- ▶ LED-UV curing
- ▶ Monitoring for drop-outs
- ▶ Less hazard
- ▶ Industry consolidation
- ▶ Vertical integration

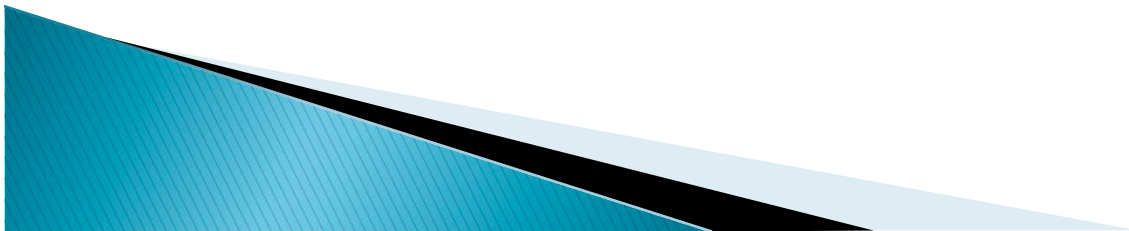
Application Requirements

- ▶ Sustainable, eco-friendly
- ▶ Hybrid with analog
- ▶ Automatic maintenance
- ▶ Print quality depends on the substrates: e.g. Print smoothness and sharpness on non-porous surfaces requires matching the surface energy of the ink with the substrate



Inkjets: Tools Among Tools

- ▶ Hybrid with other digital technologies
- ▶ Hybrid with analogue technologies
- ▶ Hybrid with subtractive digital fabrication
- ▶ Primarily additive, but also can be used for subtractive action



Inkjet Opportunities

- ▶ LCD screens, textiles, ceramics, glassware, packaging, labels, high resolution marking and coding, industrial decoration, printed electronics, antennae, RFID tags, 3-D fabrication, medicine, biological and medical technology
- ▶ Coming applications: photovoltaics, digital batteries, touch panels, fabric electronics, sensors, stress meters, internal imaging
- ▶ Digital materials, self repairing ink films

