Industrial Piezo Inkjet Printing on Plastics

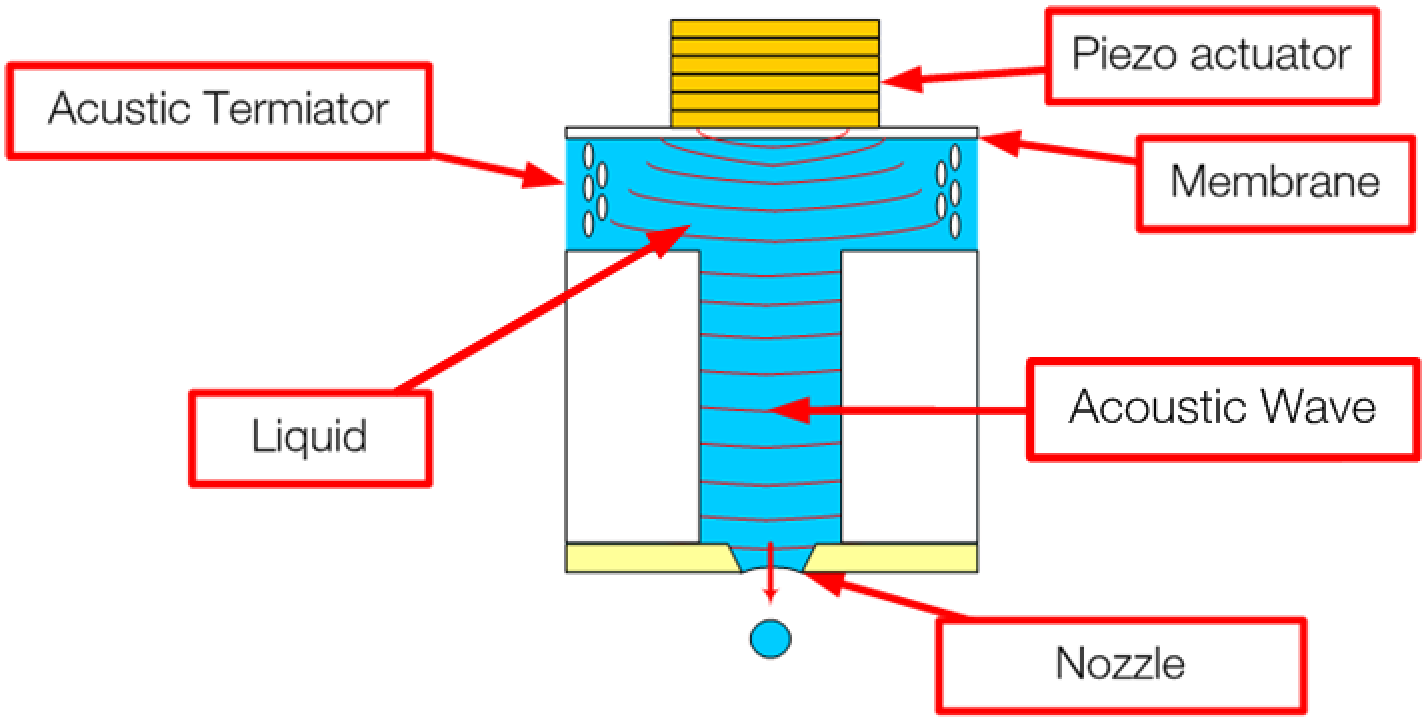
by Johannes Renner

Structure

- Industrial Piezo Inkjet Print Heads
- Substrate
- Enabling Technology
- Printer Desgin
- Conclusion
- Questions

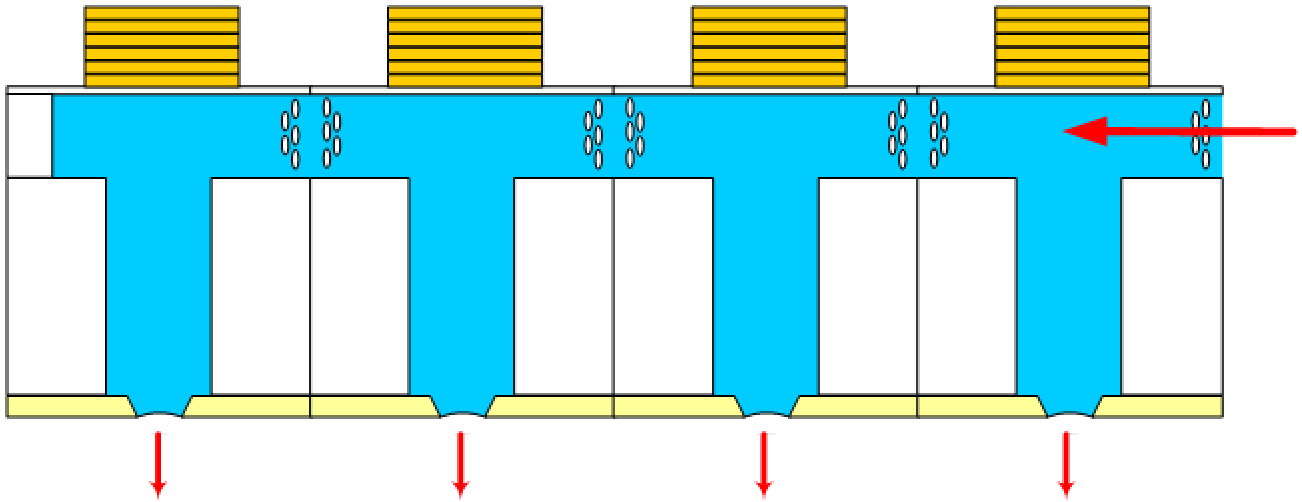
Industrial Piezo IJ Print Heads

Principle of Operation



Industrial Piezo IJ Print Heads
Principle of Operation

- Multiple Nozzles:

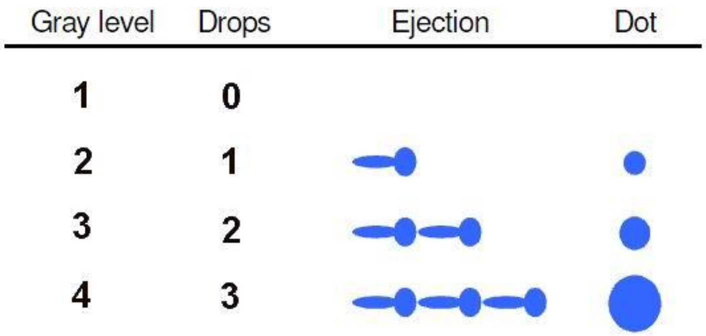


*nozzles per inch

Industrial Piezo IJ Print Heads

General Properties

- Print width 20 – 117 mm per module
- Single pass print speed 0.3 – 3.3 m/s
- Native head resolution 50 – 1200 npi*
- Dropsize 0.1 – 80 pl
- Jetting frequency 5 – 100 kHz
- Up to 16 greylevels
- Up to 5000 nozzles
- Temperature up to 120°C

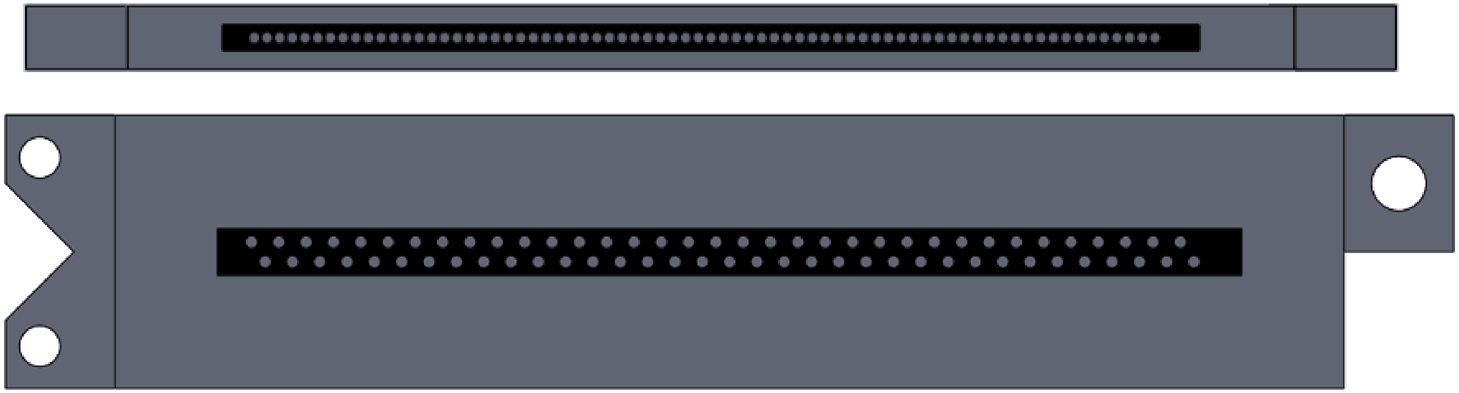


*nozzles per inch

Industrial Piezo IJ Print Heads

Typical Design

- One or multiple nozzle rows (up to 30)
- One drive pulse generator per nozzlebank
- Bigger housing with multiple nozzlebanks
- Nozzle bank Offset 0 - 30 mm



Industrial Piezo IJ Print Heads

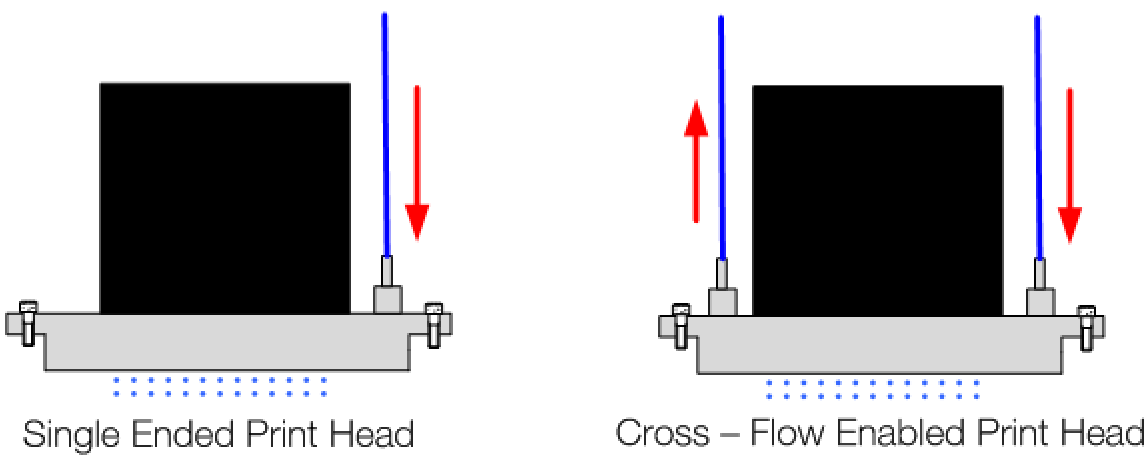
Suppliers

- ~10 Relevant suppliers
  - Dimatix (Samba, Multi printhead modules)
  - Xaar
  - Konica Minolta
  - Ricoh
  - Kyocera
  - Toshiba Tec
  - Trident
  - Seiko SIIPrinttek
  - Epson
  - …

Industrial Piezo IJ Print Heads

Liquid Flow

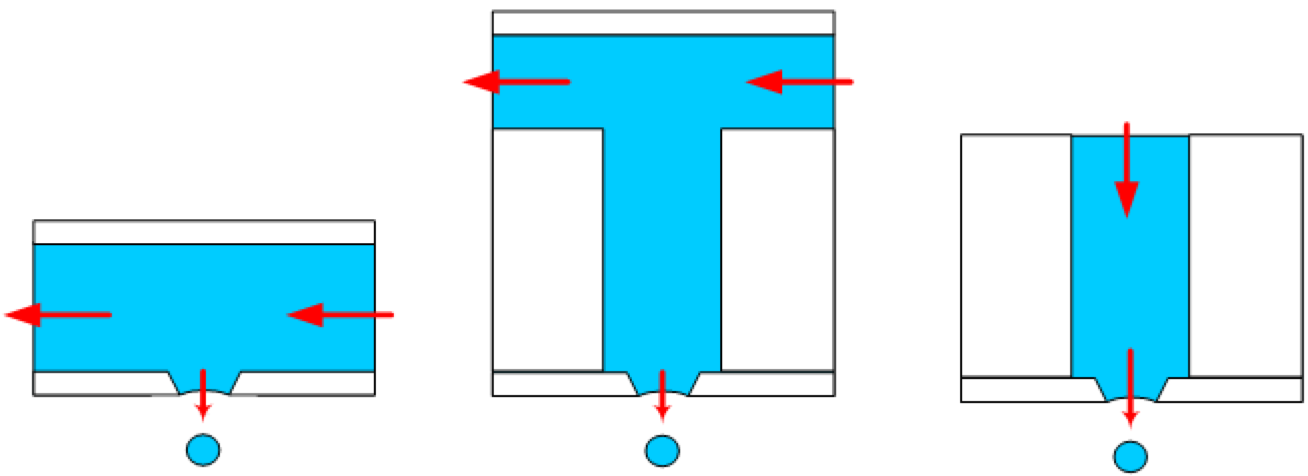
- Single ended
- Cross – flow for sedimenting inks



*nozzles per inch

Industrial Piezo IJ Print Heads
Liquid Flow

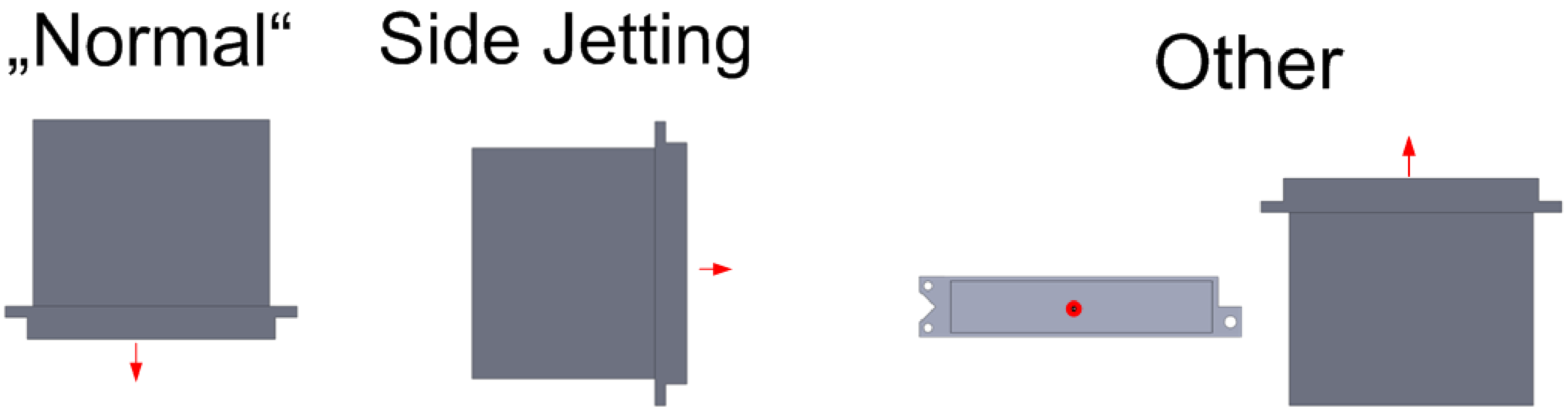
- Many printheads support indirect cross – flow
- Increasingly models for direct cross - flow



*nozzles per inch

Industrial Piezo IJ Print Heads
Possible Orientations

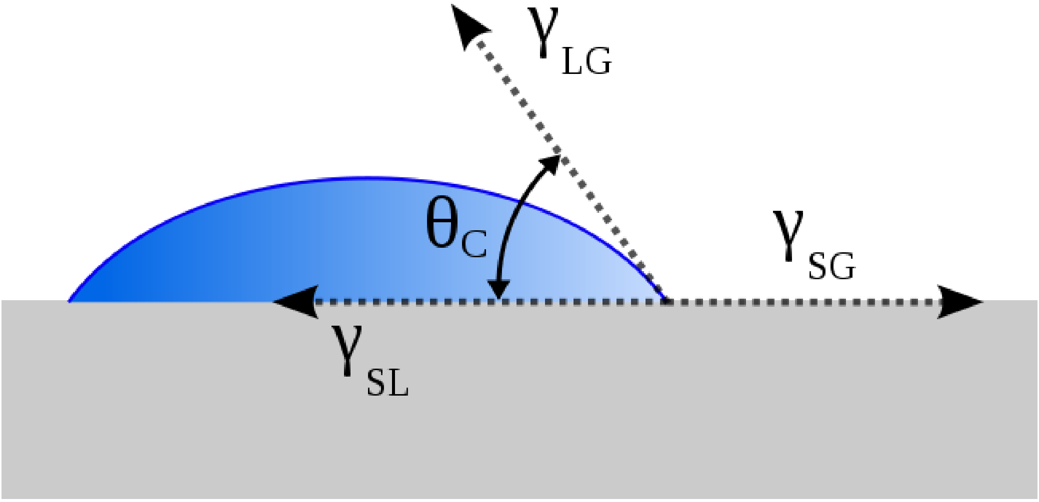
- Most printheads are intended for „normal“, vertical operation
- A lot of printheads support any orientation



Substrate

Wetting

- Due to adhesive and cohesive forces
- Requirement for adhesion
  - Depends on liquid surface tension & matieral surface energy
  - ~56 mN/m material surface energy*



Source: Wikipedia / Contact angle

*by experience

Substrate

Material

Important plastics** (without pre-treatment)		Surface Tension* [mN/m]
Polypropylene	PP	~30
Polystyrene	PS	~32
Polyethylene	PE	~35
Polyethylene Terephthalate	PET	~43
Polyimide	PI	~36
Silicone	MVQ	~24

*Typical values, measured with surface tension liquid on the substrate
** Matierial can be impure

Enabling Technology
Degassing

- To remove dissolved gas in liquid
- Required on frequencies > 10 kHz

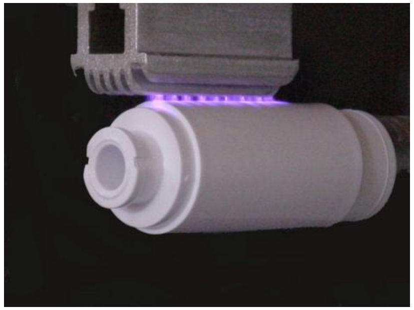
Picture: DIC degassing modules

- Membrane Vacuum Degassing
  - Vacuum Pressures ~100mBar abs.
  - Easy to integrate
- Ultrasonic degassing
  - Most efficient in combination with Vacuum
  - More expenisve to integrate

Picture: Hielscher Ultrasonics UP200S

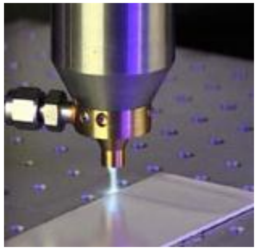
Enabling Technology
Pretreatment

- Corona
  - Discharge between two electrodes
  - Causes electrostatic Charge
- Flame
  - Controlled propane burner
  - Removes electrostatic charge
- Plasma
  - For many inks recomended
  - Most expensive



Picture: usinenouvelle.com

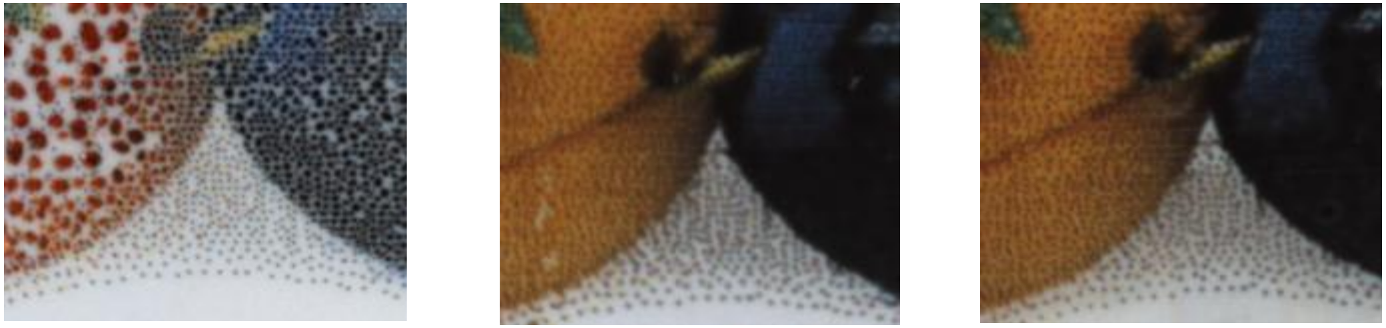
Picture: adhesives.org



Picture: Arcogas Plasma

Enabling Technology
Pretreatment

- All pretreatment methods could rise the surface tension of the substrates to >56 mN/m*
- Tested inks need **faster curing** and have **more dot gain with flame pretreatment**; few exceptions



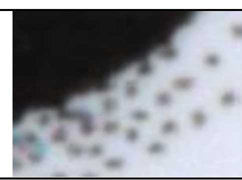
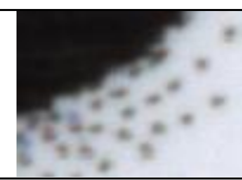
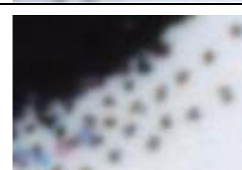
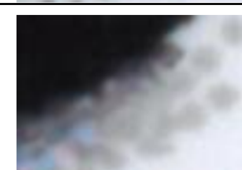
No pretreatment   Flame pretreated   Corona pretreated

All samples printed on PP with 300 mm/s

*though more ore less intense pretreatment was neccesary

Enabling Technology
Dot Gain

Comparison of dot gain with 14 pl dots on PP

Gain Flame-Corona	Flame	Corona
Ink 1 100-70 um		
Ink 2 150-100 um		
Ink 3 150-250 um		

*All Samples have identical cure delay

Enabling Technology

Types of Inkjet Inks

- UV curable – Higher viscosity
  - Radicalic curable UV inks
  - Kathionic curable UV inks
- Solvent based – Lower viscosity
  - Oil Based
  - Aqueous inks
- Hot Melt – Temperatures >60°

Enabling Technology

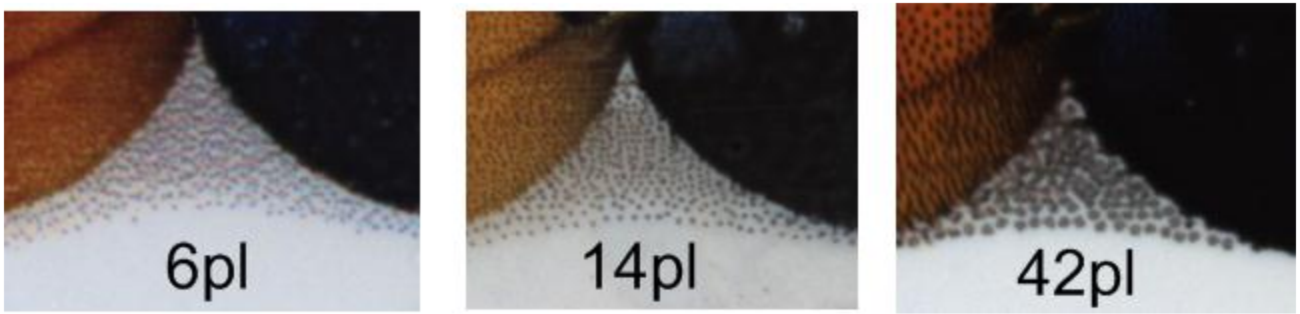
General Properties of UV Curable Inks

- Nominal jetting temperature 35 – 50°C
- Viscosity 7-12 mPas*
- Surface tension 10-30 mN/m*
- Cure energy 200 – 500 mJ/cm^2**
- Normally >2 Photoinitiators
- Shelf live 6-24 months

*at recomended jetting temperature
** Total UV output of a mercury arc lamp

Enabling Technology
Dot Gain

- Small is normally better → finer details
- Depends on ink, pretreatment, substrate,temperature…
- Typical 80 - 100 um on PP with 14 pl

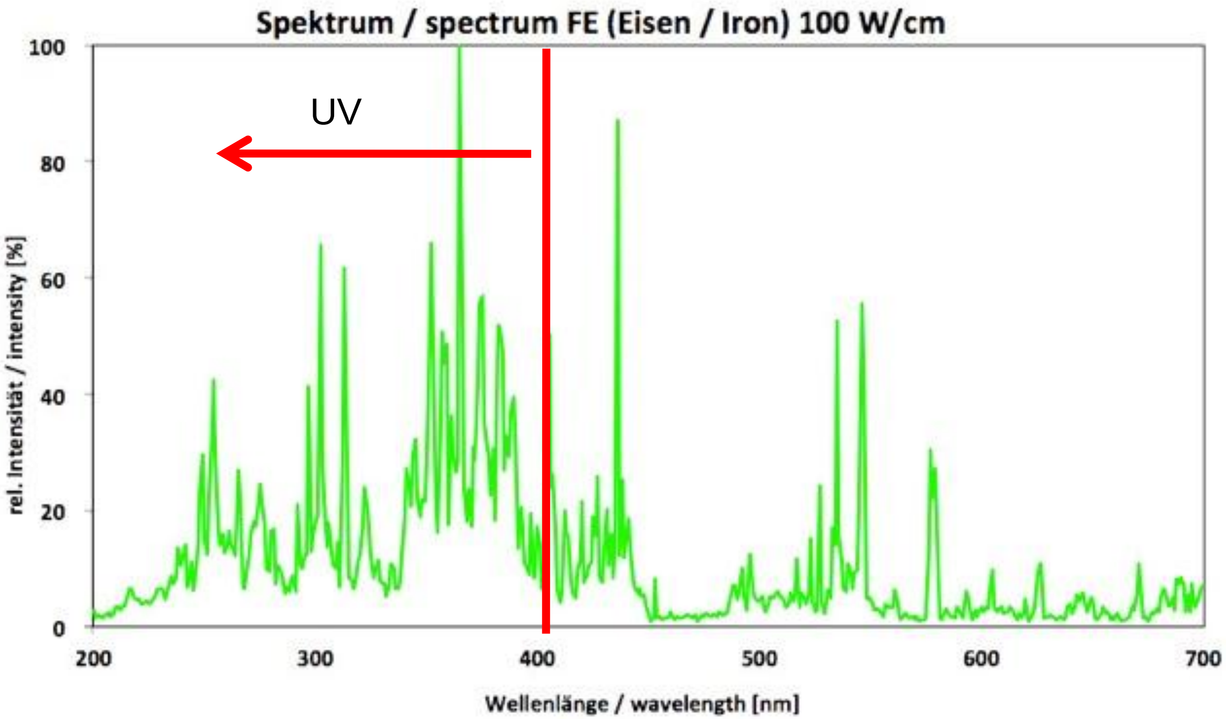


*All samples printed with 300 mm/s on PP

Enabling Technology
UV Curing

- Mercury – arc lamps
- LED Cureable inks

Pictures: Mercury Arc Lamps
(www.honle.de)

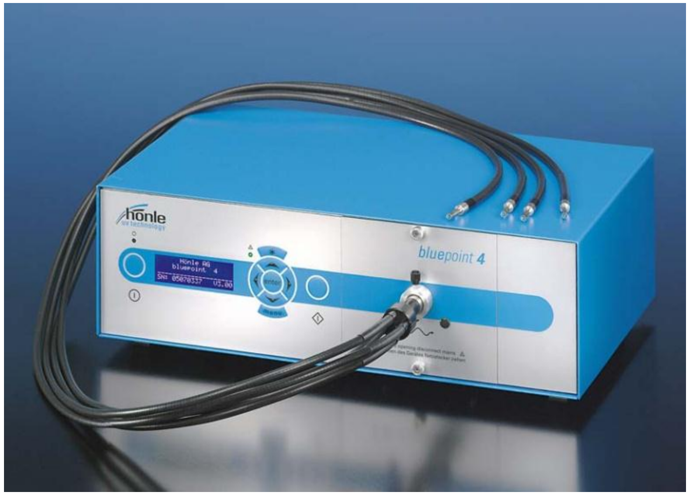


Enabling Technology
Cure Energy

- Depends on the spectral match of photoinitiators & UV source
- Typical ~100 – 500 mJ / cm^2 (with mercury-arc lamps)
- Can be reduced with intensitiy, degassing & inert gas
- Cure Energy for new inks is generally decreasing

Enabling Technology
Pinning

- Is partial curing with a weak UV source
- If minimal cure delay is too high, a solution
- Better control of the dot gain
- Can reduce ink adhesion
- For matt ink surface



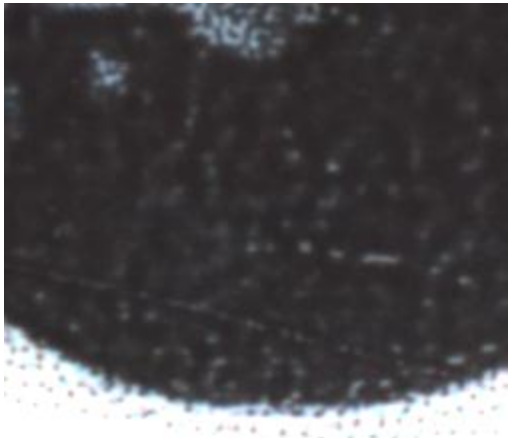
Picture: Honle Bluepoint 4

Picture: phoseon.com

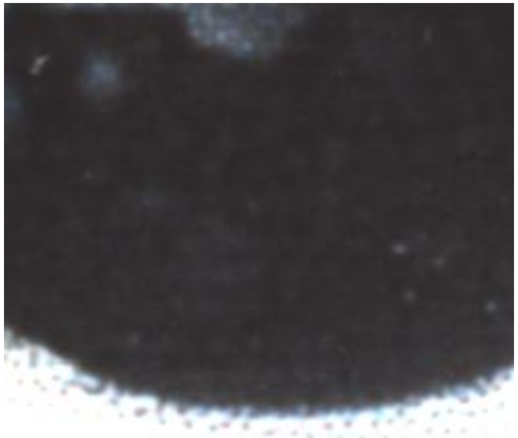
Enabling Technology
Cure Delay

- Time after print to cure (normally 0.5 to 3.5 sec)*
- Major effect on print quality & ink‘s behaviour
- Depends on the methode of pretreatment & substrate*
- Can be extended with an adhesion promoter (primer)

0.5 s



2 s

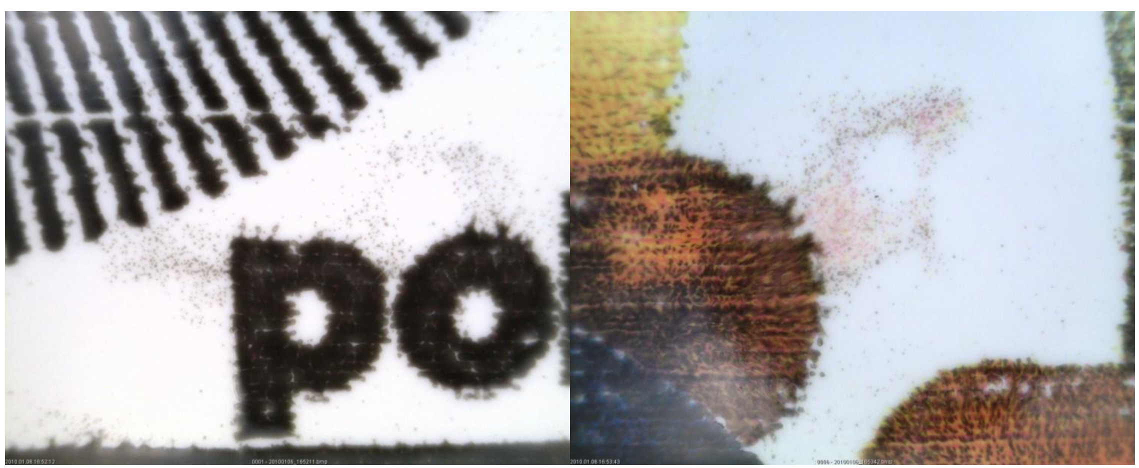


3 s

* For a similar results

Enabling Technology
Ionization

- Removes electrostatic charge on the substrate
- Affects mainly satellite droplets
- Effect hardly visible with throw distance < 2 mm

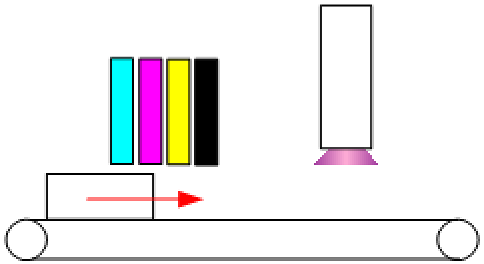


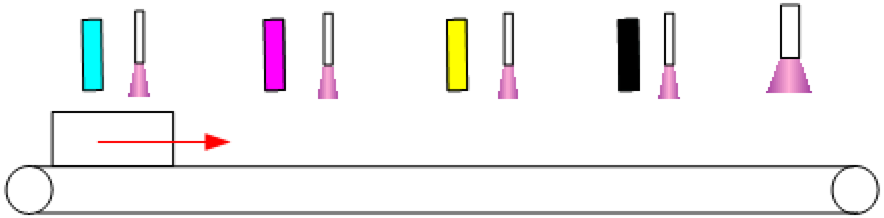
Structured clouds of satellites on charged substrate without ionization

Printer Design

Single Pass Printing Process

- Depends on ink, substrate, pretreatment and curing
- Different approaches:





Printer Design

Arrangement & Color Sequence

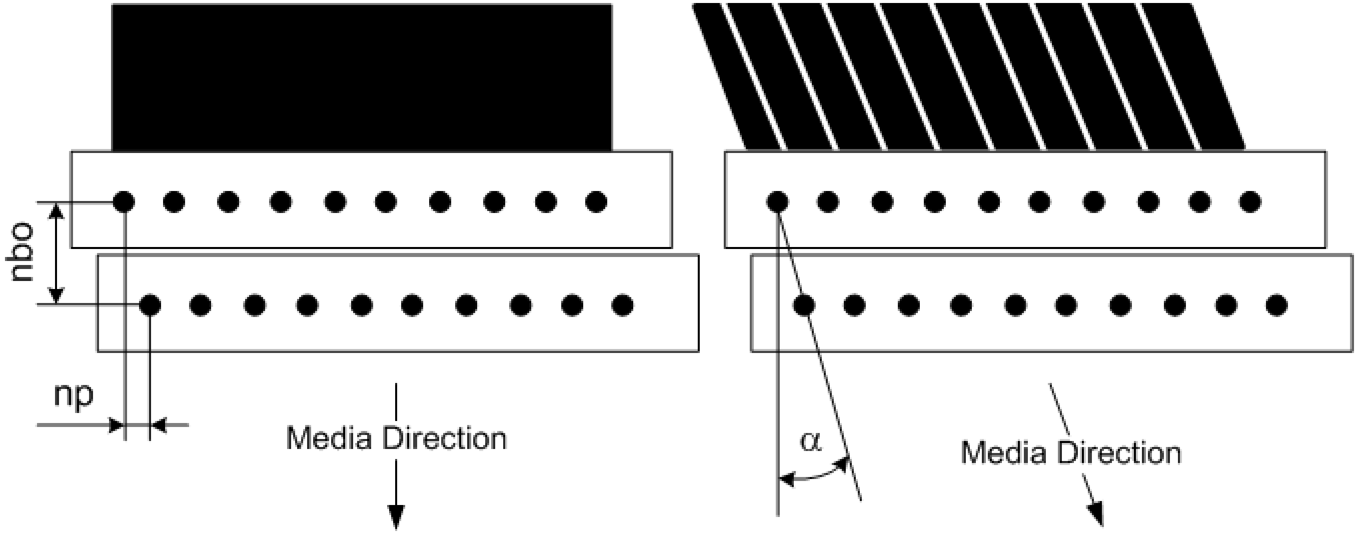
- Registration within a color should be accurate (< +/- 5 - 10 um)*
- Color to color registration may be less accurate (< +/- 50 - 100 um)*

*for 720 dpi by experience

Printer Design

Arrangement & Color Sequence

- Heads of the same color as close as possible together
- With np=70.5 um, nbo=20 mm → α=0.2°
- Angular accuracy must be better by far



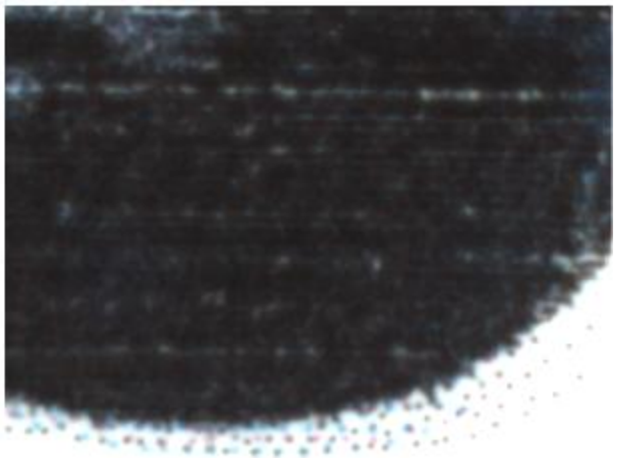
Printer Design

Throw Distance

1.5 mm
Throw distance

More satellites,
No „lines“

4.5 mm
Throw distance



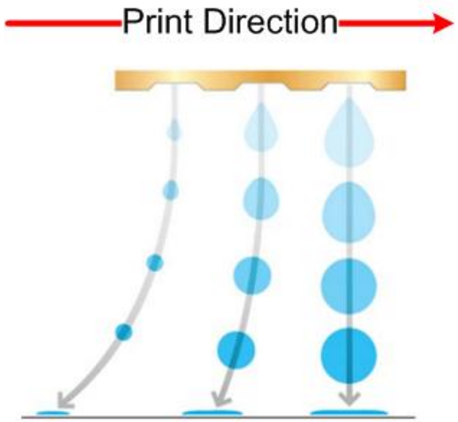
Less satellites
Disturbing „lines“

Samples printed with 14pl drops @ 300 mm/s in a single pass on PP, with corona pretreatment

Printer Design

On „High“ Throw Distance

- Jet straightness problem
- „Bigger“ Drops
- Redundand print heads
- Correction of systematic faults in two passes
- Satellite reduction against feathering



Picture: Fujifilm Dimatix;
Iml Conference, Barcelona 2009

Conclusion

- UV Inkjet for direct printing onto plastics
- Pretreatment for adhesion & wetting necessary

- Registration within a color needs to be accurate
- Printheads with high nozzle density and small nbo

- For high throw distance (> 3 mm for 14 pl), bigger drop sizes and minimization of satellites may be considered

Questions?