i4inkjet

July, 2021

About i4inkjet :

In 2020, i4inkjet Limited was set up as a registered company to continue the bimonthly publication of Directions, the ink jet industry patent and news review service which was first initiated by Mike Willis and Pivotal Resources Limited over 20 years ago.

i4inkjet Limited now owns the brand names and logos associated with 'Pivotal ink jet resources' and 'Directions' and since Mike's retirement 'Directions' is produced by Dr. Adam Strevens, director of i4inkjet Limited, who now covers the hardware reviews.

INKJET HARDWARE

All kinds of inkjet applications and systems

- **Single pass & multipass** (scanning)
- **Intermediate transfer**
- **Direct-to-object & 3D printers**
- **Components (dryers, transport, etc.)**
- **Printhead maintenance**
- **Others**

Dr. Adam Strevens

All kinds of inkjet printheads

- **TIJ** (thermal inkjet)
- **PIJ** (piezo inkjet)
- **CIJ** (continuous inkjet)
- **Recirculating & non-recirculating**
- **High and low viscosity designs**
- **Others**

All kinds of inkjet inks

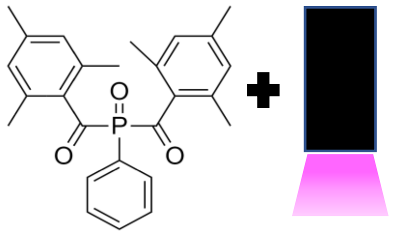
- **Aqueous**
- **UV-curable & e-beam**
- **Solvent**
- **Latex & oil-based**
- **Conductive & dielectric**
- **Others**

Dr. Phil Bentley

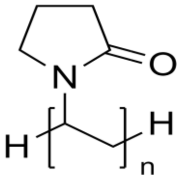
All kinds of inkjet media

- **Permeable & impermeable**
- **Laminates & tiles**
- **Paper, foils, wood & plastic**
- **Embellishments**
- **3D build materials**
- **Others**

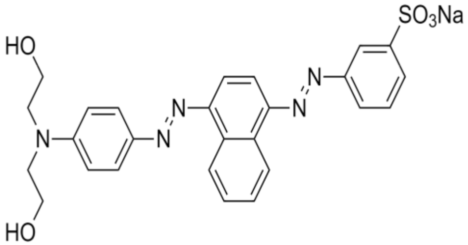
Dr. Clare Conboy



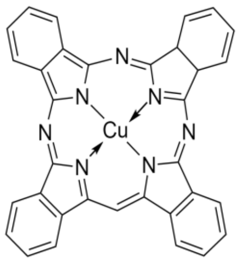
photoinitiator for UV-curable inks



aqueous-soluble binder for pigments

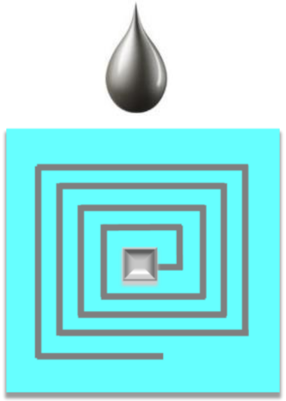


water-soluble dye

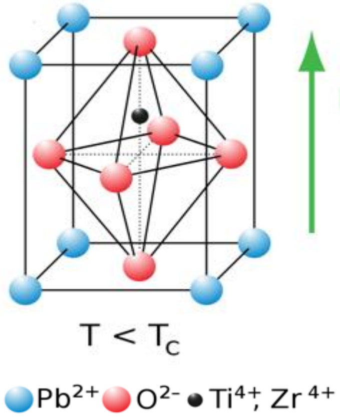


cyan pigment

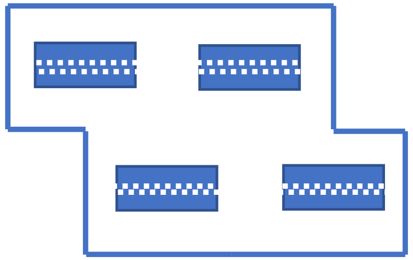
INKS

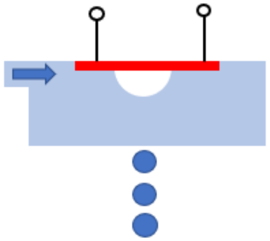


MEDIA

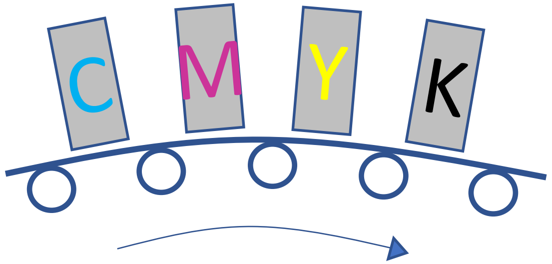


Piezo inkjet





Thermal inkjet



HARDWARE

Coverage of a wide range of companies including:

We only review technology developments which we consider to be novel and interesting for in an inkjet technology context. Because of the large number of reviews done over the past 20 years which are in our database, we can more easily justify our selection. Naturally, the big players in the inkjet industry are covered most frequently, however, the choice is of patents reviewed is always on the basis of technology rather than by company which means interesting inventions which describe useful technology steps can come from a wide range of companies. We believe our subscribers benefit from this approach and the learning that is gained from the reviews. We try our best to ensure the key inventive steps are clearly explained and with good background given in the introduction of each review. Over time Directions can become a valuable library and reference for anyone interested in tracking technology developments in the inkjet industry. In other words it is not possibly to review every company in one issue but over the period of just one year in interesting cross section of the inkjet industry which is representative of key developments is provided.

- In the publication Directions, the following section headings are always included:

TABLE OF CONTENTS

This is always about inkjet printhead designs

This is always about inkjet printers and the components used in them, and the key equipment design for a given inkjet printing application

- The following slides do not necessarily show full reviews – instead, just an excerpt from the review is provided
  - The topics chosen are just some examples showing the breadth of topics covered

Example 1. Mycronic AB

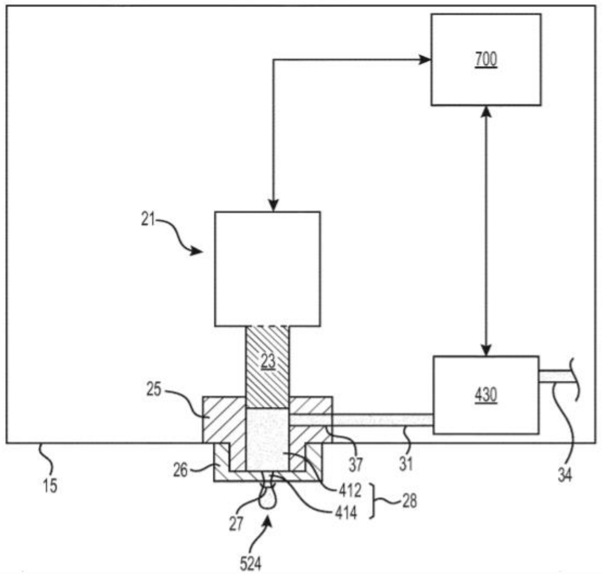
Patent review excerpt from a review on silver paste jetting device:

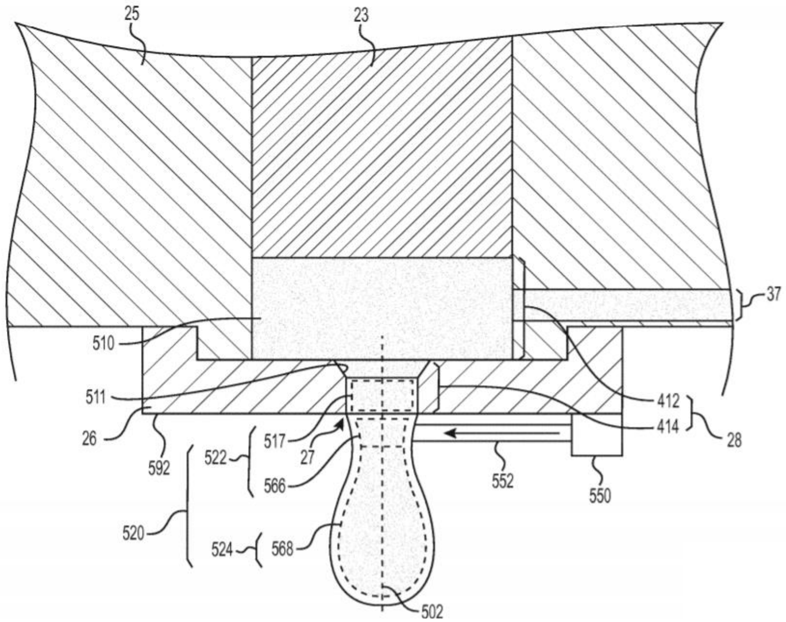
"Previous devices used for dispensing silver paste have used a piezo piston incorporated into the upper part of a cylindrical pump chamber with a nozzle at the end. At the nozzle end there is a paste feed line into the side of the chamber which is controlled by way of a screw pump with a micro-stepper. A piezo piston actuator can, in such a configuration, in principle be operated at up to about 1kHz to cause a pressure change at the nozzle which forces a drop to be ejected.

The patents here seek to improve the control of the drop formation by adding an additional energy stimulus directly at the nozzle where drop formation occurs. Three different approaches to improve drop formation control at the nozzle are discussed here. Apart from improved control, these methods are envisaged to also improve reliability of device operation when printing and reduce the number of interventions required for maintenance.

The figure top right shows a silver paste jetting device without any energy emitter, and is a cross section of the long axis of the jetting assembly. Jetting assembly enclosure 15, PZT actuator stack 21, plunger 23, plunger bushing 25, viscous fluid supply 430 and supply channel 37 are shown, together with portions of the ejection chamber 28, including internal cavity 412 and nozzle cavity 414, nozzle 26, nozzle exit 27, programmable control device 700, and ejecting drop 524.

The figure bottom right shows a laser emitter 550 and laser beam 552 external to the nozzle. An energy stimulus at the nozzle can be used for additional fine adjustment of drop formation on top of the basic piston-based arrangement. Laser-based heating in a region close to the nozzle exit causes localised heating, effectively reducing the paste viscosity making drop break-off easier and more controllable."





WO 2019/011672 A1 **Jetting devices with energy output devices and methods of controlling the same**
Mycronic AB

Example 2. Sun Chemical Corp

Patent review excerpt from a review on ebeam curable inks:

"For a range of reasons often discussed here, UV-curable ink jet inks most often use acrylates as the reactive groups of choice. The energy of a typical UV photon, particularly in the UVA and UVB regions of the UV spectrum, is below the bond energy of the double bond of the acrylate group and so curing in these systems requires the presence of photoinitiators. The energy of electron beam (eb) electrons exceeds the acrylate bond energy and so can be used to directly initiate the free-radical cure mechanism in acrylate ink jet inks.

The removal of photoinitiators has multiple advantages for ink jet inks, as they are often included at significant levels in order to overcome oxygen inhibition. Additionally, if the UV- curable formulation is meant for food packaging then care must be taken to ensure the photoinitiator residues are non-migratable, usually by increasing the molecular weight of the molecules. Thus by using an eb curing mechanism the curable ink jet ink is immediately more suitable for food packaging.

This patent runs with this advantage by formulating food packing inks with little or even no mono function monomers as these materials, after the photoinitiator, are generally the next most problematic materials with respect to migration. Multiple reactive groups have a significantly higher chance of being permanently incorporated into the cured network. However, with UV-curable ink jet inks, reducing the amount of monofunctional monomers often reduces adhesion on non-porous substrates as the shrinkage of the thick (around 10 microns) cured ink layer will be increased. this shrinkage pre-stresses the interface between the ink and the media, a bond that is generally low on such low cost food packaging substrates.

Thus, it is common practice in flexible UV-curable ink jet inks to use blends of monofunctional monomers such as n-vinyl caprolactam or ethylene glycol phenyl ether to promote adhesion to plastic substrates. Other than a reduction in shrinkage, the adhesion improvement with these specific monomers is assumed to arise from their high solvency power for the plastic substrates, allowing the film to key into the surface. this patent also suggests that the adhesion improvements of these monomers is also due to the residual monomers left in the films after cure, plasticising the ink jet film.

This patent considers the challenge of improving the adhesion of high functionality ink jet inks to packaging materials, with a focus on ensuring minimal migration of monomers from the final cured film.

The best performing exemplified formulation uses only difunctional monomers and higher, such as dipropylene glycol diacrylate (DPGDa), 2-(2-vinyloxyethoxy)ethylacrylate, 3-methyl1,5-pentanediol diacrylate and an ethoxylated trimethylolpropane triacrylate. to this monomer mix was added a surfactant, a pigment and 0.5 wt% Irgacure 815 to give an ink jet ink with a viscosity of 10 cps at 45 C, that fully passed adhesion testing on a polyester substrate when cured at an eb dose of 50 kGy. Total extractable monomers or photoinitiator were less than 20 ppb for this ink and cure dose."

WO 2017/180491 A1 **Electron beam curable inkjet formulation with improved adhesion**
Sun Chemical Corp

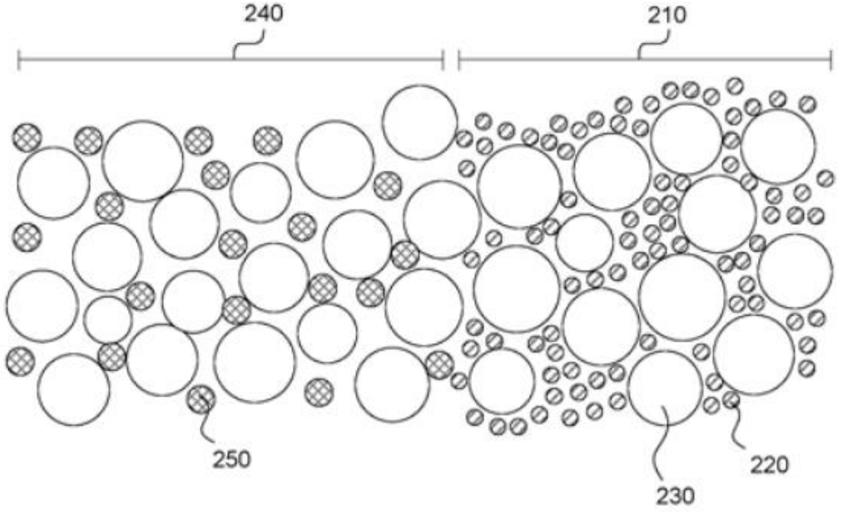
Example 3. Hewlett-Packard Development Co, LP

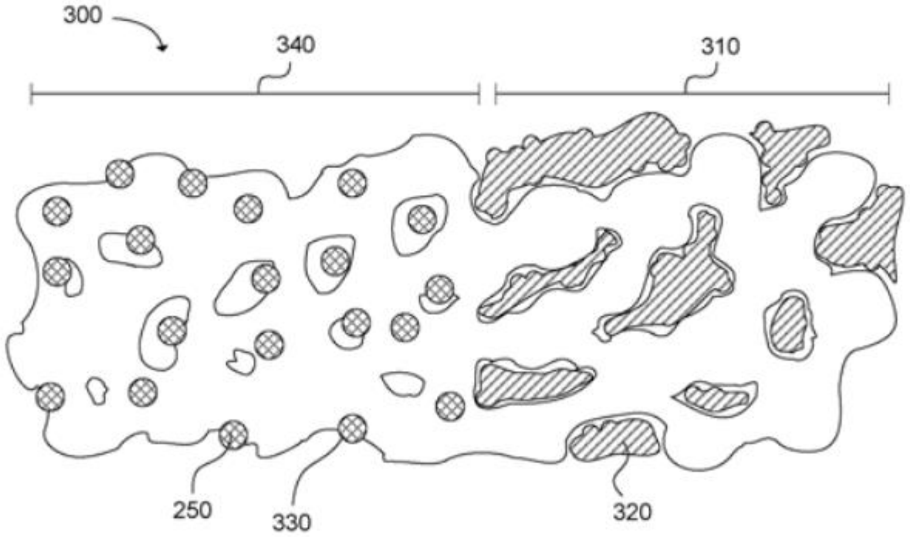
Patent review excerpt from a review on 3D printing conductive tracks:

"This patent describes a materials set for printing embedded electrical traces within a 3D printed part using the HP Inkjet Fusion printer. the basis for this printer is a thermoplastic polymer such as nylon which will have a melting point between 70 and 350C. a powder bed with a particle size of 20 to 200 µm is printed with a fusion agent that acts as a thermal energy absorber, generally containing carbon black which acts as an energy absorber. on exposure to an IR or halogen-based heating lamp, the energy is transferred to the polymer, which in turn fuses to create a solid in the areas where fusion agent has been printed. subsequently, a fresh layer of powder is spread over the printed and fused layer and the next layer of the image is printed.

Both figures on the right show cross-sectional views through the powder bed with conductive material printed on the righthand side and nonconductive materials on the left.

The top image illustrates the powder prior to fusing while the figure on the bottom shows it after fusing. In the top image thermoplastic particles 230 are shown printed with bronze particles 250 and nanometal particles 220. In the bottom image is shown the composite materials consisting of a fused thermoplastic matrix 330 with domains of sintered bronze 250 and metal 320 nanoparticles. In each case the sintered particulate domain will be interconnecting to form continuous conducting or non-conducting tracks through the fused part. The amount of conductive ink printed can be varied to give tracks with different conductivities in the x-y plane, and larger quantities of ink can be printed to form vias between the planes."

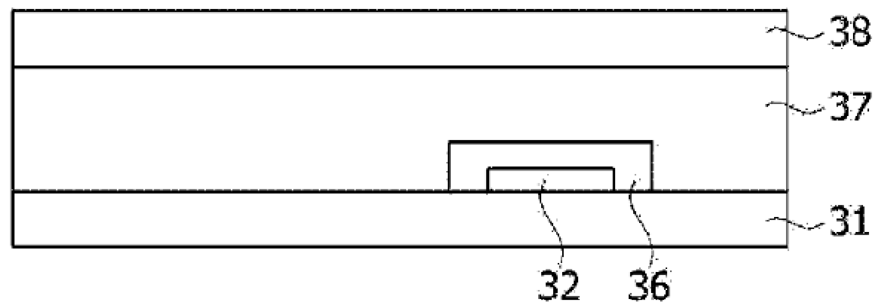




WO 2018/080438 A1 Material sets
Hewlett-Packard Development Co, LP

Example 4. LG Chem Ltd

Patent review excerpt from a review on OLED encapsulation materials:

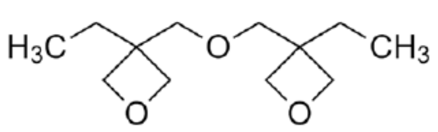


"In the device schematic shown top right, the OLED core components 32 have a sealing structure36 (not discussed in the patent), followed by the organic encapsulation layer 37 (which is discussed in these patents) and finally a cover substrate 38. The required properties for this encapsulation layer, other than having physical properties suitable for ink jet printheads, are good adhesion, an ability to efficiently planarize the device surface, and low levels of outgassing of volatiles after cure. This latter point is critically important, as any water, or, oxygen contamination of the ink would cause device failure. As these inks are deposited in controlled environments and, due to the potential for water contamination, the patents insist that the inks must be free from volatile components. This adds further complexity to the formulation if it is to remain ink jet printable. Consequently, a 100% solids UV-curable approach has been chosen.

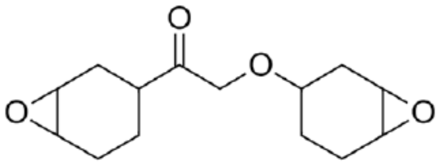
As discussed, the inks must have zero oxygen content, rendering a free-radical, curable acrylateapproach problematic, due to poor long-term stability issues. The patent has, therefore, focusedon a cationic chemistry, using a mixture of a cycloaliphatic epoxies, an oxitane and a vinyl ethermaterial to keep the viscosity to a sensible level.

The most successful formulations are comprised of limonene dioxide (10wt%), Celloxide 2021P(10wt%), 1,4-cyclohexane dimethanol divinylether (55wt%) and the oxetane OXT-221 (17wt%).These ink formulation structures are shown bottom right.

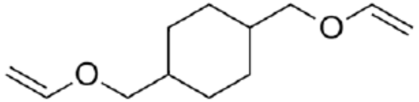
The formulation was printed using a Unijet UJ-200 using a 10pl Dimatix 256-nozzle printhead onto the substrate and allowed to planarize for forty seconds before illuminating with UV radiation at an intensity of 1000mJ/cm2 at 395nm. Adhesion of the cured fil was good and devices built using the technology appears to offer significant improvements over the comparative technologies."



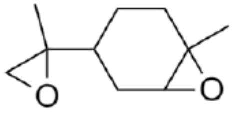
OXT-221



Celloxide 2021P



1,4-cyclo-hexane dimethanol divinyl ether



Limonene dioxide

US2020/0095456 A1 Encapsulating composition LG Chem Ltd

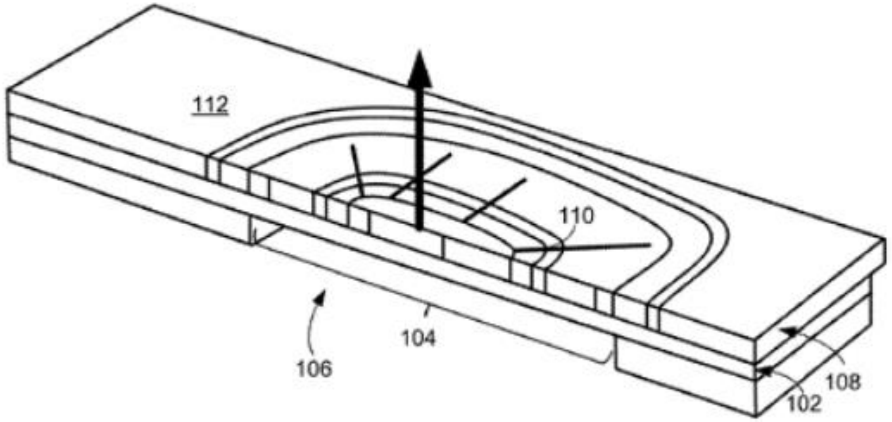
Example 5. Fujifilm Dimatix, Inc.

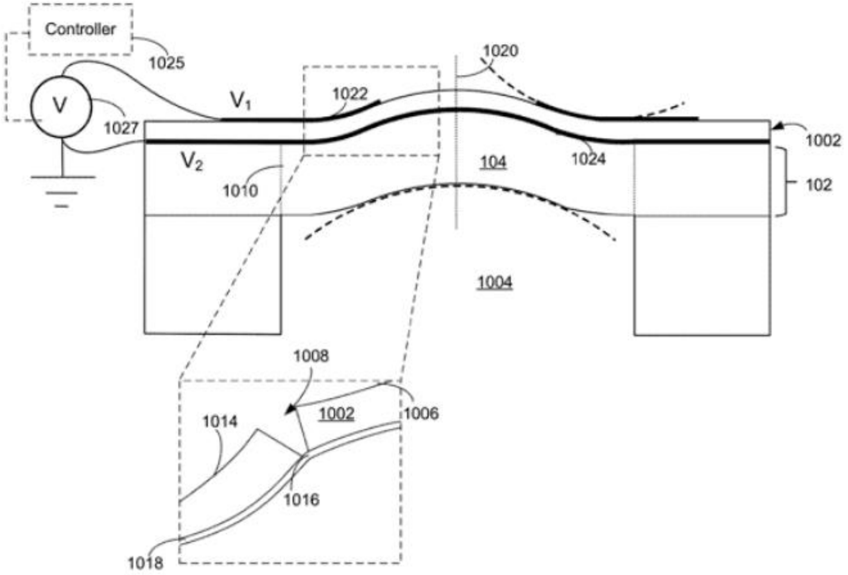
Patent review excerpt from a review on a Si-MEMS piezo printhead :

"Silicon mems printheads can be manufactured with a high density of actuator chambers, allowing high-resolution single pass printheads to be developed. However the small dimensions of the actuator chambers require thin-film piezo actuators to be used, and together these have limits to the amount of displacement, and hence pressures and drop sizes that can be generated. This patent application proposes a way to overcome this, allowing larger drop volumes to be generated from the same size actuator and at a similar voltage.

The improvement is achieved by forming trenches in the piezo layer. Here the actuator 108 is formed on the surface of a membrane 102 over the actuator chamber 104. the trenches 110 allow the piezo layer to flex to a greater extent, resulting in more displacement of the membrane for the same applied voltage.

In the image bottom right, flexing is shown in more detail. As shown in the inset, a trench 1008 has been formed through the piezo material 1002. The actuator, therefore, flexes around the trench as shown. The piezo layer is 2-5 microns thick, over a silicon or semiconductor membrane. As well as the trench acting like a hinge, the stresses that would otherwise occur within the piezo layer are reduced."

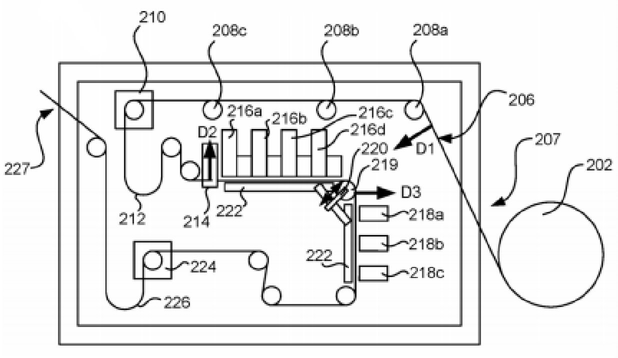


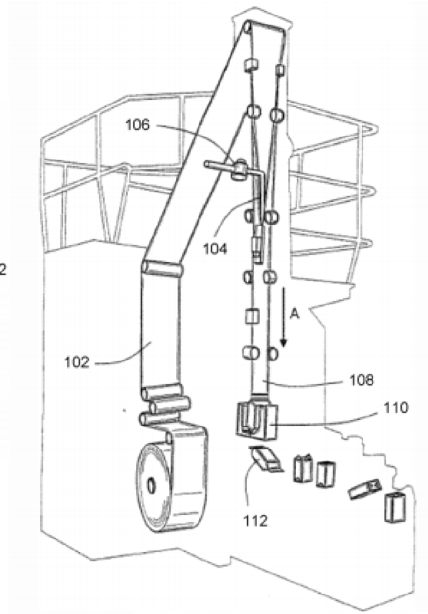


WO 2018/118774 A1 Actuators for fluid delivery systems Fujifilm Dimatix, Inc.

Example 6. Tetra Laval Holdings and Finance

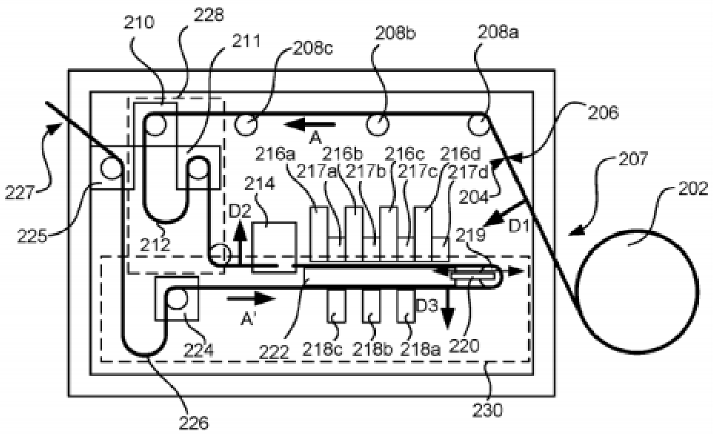
Patent review excerpt from a review on an inkjet printer for packaging:





On the far left is a side view of the digital carton printer with web 202, printbars 216 and UV ink curing lamps 218 with a metal UV light shield 222. By redirecting the web twice using web feeding assembly (208a, 208b, 208c, 210, 219, 224), the carton packaging material can be supplied in the same manner as done today (on a reel 202 with what will be the inner surface 206 of the carton facing outwards and with the laminated surface facing inwards).

- Changing business model: today printing for packaging like this is done off site by converters using flexo presses; an inkjet printer at the packaging site would be advantageous to meet the growth in demand for short-run packaging print jobs. Patents like this from large companies that are dominant in their sector are a strong indication of future technology directions.



Another digital printer configuration is shown on the left using pinning lamps 217 beside each printbar. In this space-saving configuration the curing lamps 218 are beneath the printbars, separated by metal UV shielding plate 222.

The general approaches used in both printer configurations discussed can also be used for non-liquid food products, such as potato crisps.

Further, the packaging material may pass through a sterilization device, e.g. a hydrogen peroxide bath or an LVEB (Low-Voltage Electron Beam) station. In principle, if an Ebeam source was used, it could be positioned after the ink jet printing station and both cure a food-safe Ebeam ink as well as sterilize the printed medium prior to direct entry into the filling machine.

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  - care is taken to maximise image quality and patent legibility
  - typically an original patent document is 30-50 pages long
  - key points are condensed to a 500 - 800 word review, depending on patent length and content
  - often more than one patent from a company on a given inventive idea is published in a given 2-month period. In some of these cases patents are helpfully grouped to convey a more complete picture

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