Ink composition, ink set, method for preparing an ink composition, printing method and printer.

The present invention relates to a radiation-curable gelling ink composition. The present invention further relates to an ink set and to a method for preparing to a radiation-curable gelling ink composition. In addition, the present invention relates to a method for printing and a printer.

Background of the invention

Methods for applying an image onto a recording medium using a radiation-curable ink composition are known in the art. Generally, such methods comprise the step of applying the radiation-curable ink onto a recording medium, e.g. by jetting droplets of the ink using an ink jet printer. After the ink has been applied onto the recording medium, the ink is irradiated using a suitable type of radiation to harden the ink. The ink may be irradiated using a curing unit configured to in operation emit a suitable type of radiation, such as UV radiation.

Radiation-curable gelling ink compositions are a special class of radiation-curable ink compositions. These inks are fluid at elevated temperatures and are in a gelled state at lower temperatures. In the gelled state, the viscosity of the ink is high, preventing the ink to flow. Radiation-curable gelling ink compositions are typically jetted at elevated temperatures and cool down rapidly after being deposited onto the recording medium, to form an image. Because of the increased viscosity of the ink after being deposited onto the recording medium, the ink need not be cured instantaneously after being deposited onto the recording medium. Instead, there can be a time interval being applying the ink and curing the ink, such as a time interval in the range of from 10s -100s. Alternatively, the ink can be pinned (i.e. partially cured) shortly after being applied onto the recording medium and afterwards, such as a time interval in the range of from 10s -100s, fully cured.

A known problem of printing using radiation-curable gelling inks is that adhesion of the cured ink layer to the recording medium may be insufficient.

Therefore a need exists for applying an image having improved adhesion to the recording medium. Further, a need exists for applying an image having improved adhesion on a wide variety of recording media.

It is therefore an object of the present invention to provide an ink composition that, when printed onto a recording medium, provides images with improved adhesion.
It is another object of the present invention to provide a printing method and a printer suitable for performing such a method.

Summary of the invention

The object of the invention is achieved in a radiation-curable gelling ink composition, the radiation-curable gelling ink composition comprising a radiation-curable matrix and one or more gellants, the radiation-curable matrix consisting of one or more radiation-curable components and one or more inert resins, wherein the radiation-curable matrix has a double bond density (DBD) and an average functionality (average F), the double bond density (DBD), the DBD being defined as:

$$DBD = \frac{\sum_{i=1}^{n} \left(f_i * \frac{(wt\%)_i}{(m_w)_i} * 1000 \right)}{100}$$

and the average functionality being defined as:

$$Average\ F = \frac{\sum_{i=1}^{n} \left(f_i * \frac{(wt\%)_i}{(m_w)_i} * 1000 \right)}{\sum_{i=1}^{n} \left(\frac{(wt\%)_i}{(m_w)_i} * 1000 \right)}$$

wherein the DBD is higher than 3 and the average functionality is in the range of from 0.9 to 1.25.
From the above definition of the double bond density (DBD) it follows that the unit of the DBD is “mol/gram”. Further, from the definition of the average functionality (average F), it follows that the average functionality is a dimensionless number.
The radiation-curable gelling ink composition consists of a radiation-curable matrix and a remainder-ink-composition. The radiation-curable matrix consist of one or more radiation-curable components and one or more inert resins. The remainder ink composition may not comprise any radiation-curable component. Further, the remainder ink composition may not comprise any inert resin. The remainder ink composition may comprise for example one or more photo initiators, one or more gellants, one or more inhibitors, one or more colorants and/or one or more dispersants.
The radiation-curable matrix and the remainder-ink-composition together are present in

100 wt%, based on the total weight of the radiation-curable gelling ink composition.
A radiation-curable ink composition is an ink composition that can be cured using a suitable type of radiation. UV-radiation may be an example of a suitable type of radiation.

The radiation-curable gelling ink composition may comprise a radiation-curable matrix. The radiation-curable gelling ink composition may comprise further components in addition to the components comprised in the radiation-curable matrix, such as one or more colorants, one or more dispersants, one or more solvents and/or one or more co-solvents, one or more photo initiators, one or more sensitizers and/or one or more co-initiators, one or more inhibitors, and/or one or more surfactants. The further components may from the remainder-ink-composition. The colorants may be dyes or pigments. Preferably, the colorant is a pigment, or a combination of more than one pigment. The one or more solvents and the one or more co-solvents may preferably not comprise a functional group capable of undergoing a polymerization reaction upon activation with UV radiation.

The radiation-curable matrix may comprise one or more radiation-curable components. The one or more radiation-curable components may comprise radiation-curable monomers and/or radiation-curable oligomers.

The monomers and oligomers may be monofunctional (i.e. one polymerizable group per molecule), difunctional (i.e. two polymerizable groups per molecule), trifunctional (i.e. three polymerizable groups per molecule), tetrafunctional (i.e. four polymerizable groups per molecule), or multifunctional (i.e. five or more polymerizable groups per molecule).

Examples of radiation-curable monomers are (meth)acrylates, epoxides, vinyls, vinylethers, vinyl esters, vinylether acrylates, allyl ethers, allyl esters, acrylamides, methacrylamides, styrenes, maleates, fumarates and itaconates.
Examples of radiation-curable oligomers include urethane acrylate oligomers, polyester oligomers, amine functionalized oligomers, polyether oligomers, polyamide oligomers, acrylate oligomers and epoxy based materials such as bisphenol A epoxy acrylates and epoxy acrylates.

Preferably, the one or more radiation-curable components may comprise one or more acrylates. Preferably, the one or more radiation-curable components may comprise a monofunctional components and a non-monofunctional component, such as a

difunctional, trifunctional, tetrafunctional and polyfunctional component.
Further, the radiation-curable matrix may comprise at least one amine acrylate. Amine acrylates are also known as acrylated amines. Amine acrylates may improve the surface curing of the ink layer upon exposure to radiation, such as UV radiation.

The radiation-curable matrix may further comprise one or more resins.
The resin is an inert resin, i.e. a resin not comprising polymerizable groups. Examples of resins are polyurethane resins, polyester resins, acrylic resins, polystyrene resins, acrylic copolymer resins, such as acrylic-styrenic resins, polyolefin resins, such as polyethylene resins, polypropylene resins, ethylene-propylene copolymeric resins, MMA copolymer, polyester amide, benzoates, polyvinyl acetate, polybutyl acetate, ketone resin, cellulose esters, (modified) rosin resins, poly vinyl butyral resins, vinyl chloride resins, ketone-aldehyde condensation resins and polyol resins, such as polyester polyol resins.
The addition of an inert resin may improve the properties of a cured ink layer.
In an embodiment, the one or more inert resins may be selected from acrylic resins, styrenic resins and/or styrene-acrylic resins.

The radiation-curable matrix may consist of one or more radiation-curable components and one or more inert resins.

The radiation-curable gelling ink composition may comprise one or more gellants. A gellant is also referred to as a gelling aid, gelator, gelling agent or thickener.
The presence of one or more gellants can cause a viscosity increase in the inkjet ink composition upon cooling of the ink composition. The viscosity increase in the ink composition should be sufficient, to adequately control droplet spreading.
Examples of gellants used in gelling radiation curable inkjet ink compositions are waxes, such as paraffin wax, microcrystalline wax, polyethylene waxes, polypropylene waxes, curable waxes and natural waxes, such as animal-based waxes or plant-based waxes, fatty acids, fatty alcohols, ketones, fatty acid esters, such as fatty acids of pentaerythritol and/or fatty acid esters of dipentaerythritol; and fatty acid amides. Because gelling inks have reduced spread of ink on the recording medium, due to their gelling property, it may not be necessary to cure the ink droplets immediately after applying them onto the recording medium. It is possible to keep the droplets in an uncured state on the recording medium, without color bleeding occurring. The gellant may be present in an

amount of from 0.1 wt% to 15 wt% based on the total weight of the ink composition, preferably from 0.2 wt% to 10 wt% based on the total weight of the ink composition, more preferably from 0.3 wt% to 5 wt% based on the total weight of the ink composition.

The radiation-curable gelling ink composition may further comprise one or more photo initiators. Photoinitiators can be divided in Norrish type I and Norrish type II photoinitiators. Each of these types of photoinitiators comprises of several classes of photoinitiators.

Examples of classes of photoinititaors that are Norrish type I photoinititiators include benzil ketals, benzoin ethers, acylphosphine oxides, α,α- dialkoxyacetophenones, α-hydroxyalkylphenones, α-aminoalkylphenones, acylphosphine oxides, acylphosphine sulphides, α-haloketones, α-halosulfones, phenylglyoxalates, peroxy compounds, O-acyl α-oximinoketons, acylphosphonates,thiobenzoic S esters, azo compounds, Triazines and biimidazoles. Examples of classes of photoinititaors that are Norrish type II photoinititiators include xanthones, thioxanthones, benzophenones, 1,2-diketones, α-ketocoumarins, phenylglyoxylates and anthraquinones.

Optionally, radiation-curable matrix may comprise a combination of non-polymeric, polymeric and/or polymerizable photo initiators. The one or more photo initiators may be present in an amount of from 0.2 wt% to 15 wt%, based on the total weight of the ink composition. Preferably, the one or more photo initiators may be present in an amount of from 2.0 wt% to 12 wt%, based on the total weight of the ink composition, such as from 5.0 wt% to 10 wt%, based on the total weight of the ink composition.

The radiation-curable gelling ink composition may further comprise one or more sensitizers and/or one or more co-initiators. Co-initiators are also known as synergists. Examples of co-initiators suitable for use in radiation-curable ink compositions are known in the art, including amine synergists. Amine synergist can be monomeric, dimeric, trimeric, oligomeric or polymeric. Examples of monomeric amine synergists include ethyl-4-dimethylaminobenzoate and 2-ethylhexyl-4-dimethylamino benzoate. Examples of a dimeric amine synergist include Omnipol ASA, Jiuri cure A151; Speedcure 7040 and Esacure A198 . The one or more co-initiators may be present in an amount of from 0.2 wt% to 10 wt%, based on the total weight of the ink composition. Preferably, the one or more co-initiators may be present in an amount of from 0.5 wt% to 7 wt%, based on the total weight of the ink composition, such as from 0,8 wt% to 5 wt%, based on the total weight of the ink composition.

The radiation-curable gelling ink composition may further comprise one or more inhibitors. An inhibitor is also known as a stabilizer. The presence of the one or more inhibitors may prevent unwanted polymerization reaction when the ink is stored. The presence of the one or more inhibitors may increase the shelf life of the ink.

Several classes of inhibitors are known, including, but not limited to, nitroxy based inhibitors, such as Irgastab UV10, OHTEMPO and TEMPO; and phenolic inhibitors, for example hydroquinone, butylhydroxytoluene, 4-methoxyphenol (MEHQ) and 2,6-di-tert-butyl-N,N-dimethylamino-p-cresol.

The one or more inhibitors may be present in an amount of from 0.005 wt% to 2 wt%, based on the total weight of the ink composition. Preferably, the one or more inhibitors may be present in an amount of from 0.1 wt% to 1 wt%, based on the total weight of the ink composition, such as from 0,2 wt% to 0.5 wt%, based on the total weight of the ink composition.

The radiation-curable gelling ink composition may further comprise one or more surfactants. The presence of one or more surfactants may lower the surface tension of the ink composition, improving the ability of the ink composition to flow. Suitable surfactants for use in a radiation-curable ink composition are known in the art.

In an embodiment, one or more of the one or more surfactants may comprise a reactive group, such as an acrylate functional group. The one or more surfactants may be present in an amount of 0.1 wt% to 3 wt%, based on the total weight of the ink composition. Preferably, the one or more surfactants may be present in an amount of from 0.4 wt% to 2 wt%, based on the total weight of the ink composition, such as from 0,5 wt% to 1 wt%, based on the total weight of the ink composition.

The radiation-curable gelling ink composition, in particular the remainder-ink-composition, may comprise further components. These further components may include one or more solvents, one or more-co-solvents, one or more colorants, one or more dispersants. One or more antibacterial component and/or one or more anti-fungi component.

Preferably, the ink composition is an inkjet ink composition, i.e. an ink composition that is suitable for being jetted using an inkjet print head.

The radiation-curable matrix of the radiation-curable gelling ink composition according to the present invention has an double bond density DBD), the double bond density (DBD)

being defined as:

$$DBD = \frac{\sum_{i=1}^{n} \left(f_i * \frac{(wt\%)_i}{(m_w)_i} * 1000 \right)}{100}$$

wherein the DBD is higher than 3.

The term f_i refers to the functionality of the individual components in the radiation-curable matrix; the term $(wt\%)_i$ refers to the weight percentage, with respect to the total weight of the radiation-curable gelling ink composition, in which the individual components is present; and the term $(m_w)_i$ refers to the molecular weight of the individual components in the radiation-curable matrix. The functionality of a component refers to the number of reactive groups. In this context, a reactive group may be a group that is capable of undergoing a polymerization reaction. A monofunctional monomer may have a functionality of one; a difunctional monomer may have a functionality of two; a trifunctional monomer may have a functionality of three, etc.

The radiation-curable matrix comprises a 1st, 2nd,3rd ……, and nth component. For each of these components, the product "f_i *($(wt\%)_i$ /$(m_w)_i$)) * 1000 " is calculated. The products of all the components of the radiation-curable matrix are added up and the resulting sum is divided by 100, resulting in the DBD. In the radiation-curable gelling ink composition according to the present invention, the DBD is higher than 3. Preferably, the DBD is higher than 3.25, more preferably higher than 3.5, for example higher than 3.75, such as higher than 4.

The radiation-curable matrix of the radiation-curable gelling ink composition according to the present invention has an average functionality (average F), wherein the average functionality is defined as:

$$Average\ F = \frac{\sum_{i=1}^{n} \left(f_i * \frac{(wt\%)_i}{(m_w)_i} * 1000 \right)}{\sum_{i=1}^{n} \left(\frac{(wt\%)_i}{(m_w)_i} * 1000 \right)}$$

wherein the average functionality is in the range of from 0.9 to 1.25.

For each of the components in the radiation-curable matrix, the product "f_i *($(wt\%)_i$ /$(m_w)_i$)) * 1000 " is calculated. The products of all the components of the radiation-curable matrix are added up, and form the numerator of the above fraction.

Further, for each of the components in the radiation-curable matrix, the product "$((wt\%)_i /(m_w)_i))$ * 1000 " is calculated. The products of all the components of the radiation-curable matrix are added up, and the resulting sum forms the denominator of the above fraction. Dividing the numerator by the denominator gives the average functionality of the radiation-curable matrix. In the radiation-curable gelling ink composition according to the present invention, the average F is in the range of from 0.9 to 1.25.

It was surprisingly found that a radiation-curable gelling ink composition, comprising one or more resins and comprising a radiation-curable matrix having a double bond density of more than 3 and having an average functionality in the range of from 0.9 to 1.25, may provide image having good adhesion onto wide variety of recording media. In an embodiment, the average F is in the range of from 1.0 to 1.2, for example from 1.01 to 1.15, such as from 1.05 to 1.10.

In an embodiment, the one or more resins may present in an amount of from 2 wt% to 30 wt% based on the total weight of the radiation-curable gelling ink composition. Preferably, the resin may be present in an amount of from 5 wt% to 25 wt% based on the total weight of the radiation-curable gelling ink composition, more preferably in an amount of from 7 wt% to 20 wt% based on the total weight of the radiation-curable gelling ink composition, such as form 8 wt% to 15 wt% based on the total weight of the radiation-curable gelling ink composition.
In case the resin is present in an amount of less than 2 wt%, based on the total weight of the radiation-curable gelling ink composition, the ink may not show good adhesion on a wide variety of substrates. In case the resin is present in an amount of more than 30 wt%, based on the total weight of the radiation-curable gelling ink composition, the jettability of the ink may be insufficient.

In an embodiment, the resin may have a molecular weight (M_w) in the range of from 1000 g/mole to 75000 g/mole, such as from 2000 g/mole to 50000 g/mole, for example from 5000 g/mole to 25000 g/mole.

In an embodiment, the one or more radiation-curable components are present in an amount of from 40 wt% to 90 wt% based on the total weight of the radiation-curable gelling ink composition. Preferably, the one or more radiation-curable components may be present in an amount of from 50 wt% to 85 wt% based on the total weight of the

radiation-curable gelling ink composition, more preferably in an amount of from 60 wt% to 80 wt% based on the total weight of the radiation-curable gelling ink composition, such as form 70 wt% to 79 wt% based on the total weight of the radiation-curable gelling ink composition.

In case the one or more radiation-curable components are present in an amount of less than 40 wt%, based on the total weight of the radiation-curable gelling ink composition, the ink may not provide a robust layer after curing.

In an embodiment, the one or more monofunctional radiation-curable components are present in an amount of from 35 wt% to 80 wt% based on the total weight of the radiation-curable gelling ink composition.

Preferably, the one or more monofunctional radiation-curable components may be present in an amount of from 40 wt% to 75 wt% based on the total weight of the radiation-curable gelling ink composition, more preferably in an amount of from 45 wt% to 70 wt% based on the total weight of the radiation-curable gelling ink composition, such as form 50 wt% to 65 wt% based on the total weight of the radiation-curable gelling ink composition.

In case the one or more monofunctional radiation-curable components are present in an amount of less than 35 wt%, based on the total weight of the radiation-curable gelling ink composition, the viscosity of the ink may be too high, which may result in an ink composition that is difficult to eject using an inkjet print head. In case the one or more monofunctional radiation-curable components are present in an amount of more than 80 wt%, based on the total weight of the radiation-curable gelling ink composition, the amount of uncured monomers present in the ink layer after curing may be too high.

In an embodiment, the radiation-curable gelling ink composition further comprises a colorant, such as a pigment, a dye or a mixture thereof. Further, the radiation curable inkjet ink composition may comprise a mixture of dyes and/or a mixture of pigments. The colorant may provide the ink composition with a predetermined color.

In an aspect of the invention, an inkset is provided, the inkset comprising a first radiation-curable gelling ink composition and a second radiation-curable gelling ink composition, the first radiation-curable gelling ink composition being an ink composition according to the present invention and comprising a first colorant, the second radiation-curable gelling ink composition being an ink composition according to the present

invention and comprising a second colorant, different from the first colorant.

An ink set may comprise a plurality of different inks. For example, the ink set may be a CMYK ink set, comprising a Yellow, a Magenta, a Cyan and a blacK ink composition. The ink set may further comprise additional colors, such as white, red, green, light magenta, light cyan and/or grey. Further, the ink set may comprise one or more metallic ink compositions. Optionally, the ink set may comprise an undercoat and/or an overcoat composition. The undercoat and/or overcoat composition may be colorless ink compositions.

At least two inks of the ink set may comprise a polymeric photoinitiator and a non-polymeric photoinitiator.

An ink set, wherein at least two of the ink compositions are radiation-curable gelling ink composition according to the present invention, may provide prints having good adhesion on a variety of recording media.

In an aspect of the invention, a method for preparing an radiation-curable gelling ink composition according to the present invention is provided, the method comprising the steps of:

a. providing one or more one or more radiation-curable components;
b. providing one or more gelling agents;
c. providing one or more inert resins;
d. mixing the one or more gelling agents, the one or more radiation-curable components, and the one or more inert resins.

The method is thus configured for preparing an ink composition according to the present invention. The one or more gelling agents, one or more radiation-curable components, and one or more inert resins may be provided. Optionally, additional components may be provided, for example an additional solvent, one or more photo initiators, one or more co-initiators, one or more inhibitors and one or more surfactants. The one or more gelling agents, one or more radiation-curable components and one or more inert resins may be provided neat or they may be provided in a solution or dispersion. Optionally, a colorant may be provided. In case the colorant is a pigment, the pigment is preferably provided as a dispersion, such as a dispersion of the pigment in one or more acrylates. A pigment dispersion may comprise one or more dispersants and/or one or more synergists. The components may be provided at once, or the components may be added subsequently. The components may be added in any suitable order. In case a dispersible component is added (e.g. a pigment), such dispersible component may be

preferably added after the other components of the ink composition are provided. Mixing of the components may be carried out at any suitable temperature, for example a temperature in the range of 50ºC - 100ºC, preferably a temperature in the range of from 60ºC - 85ºC. Optionally, the ink may be filtered after mixing the components to remove unwanted solid particles form the ink composition.

In an aspect of the invention, a method for printing an image onto a recording medium is provided, the method comprising the steps of:

a. jetting droplets of a radiation-curable ink composition according to the present invention onto the recording medium;
b. curing the radiation-curable gelling ink composition by irradiating the ink composition using UV radiation.

In the method, an image is applied onto a recording medium. In the method, in step a), an image is applied to the recording medium. The image may be applied using an ink composition according to the present invention. The ink composition may be applied onto the recording medium in a predetermined fashion, e.g. in accordance with image files stored on suitable storing means. The image may be applied for example by jetting droplets of the radiation-curable ink composition using an inkjet print head.
The recording medium may be in an absorbing medium or non-absorbing medium. Examples of recording media include plain paper, vinyl, corrugated cardboard, folding carton, coated inkjet paper, uncoated inkjet paper, wall paper and fabrics. Further examples of recording media include polyalkylene media, such as polyethylene or polyprolylene, for example fluted PP; polystyrene media, PMMA films, PMMA rigids, polycarbonate rigids, dibond media, and polyester films, such as LFM450 and IJM778. The recording medium may be a sheet-like medium, such as a sheet of paper or a sheet of vinyl. Alternatively, the recording medium may be a rigid media.
In the method, in step b), the radiation-curable gelling ink composition is cured by irradiating the ink composition using UV radiation. The inkjet ink composition may be irradiated using a suitable source of radiation, such as a halogen lamp, a mercury lamp and/or a LED lamp. Optionally, a plurality of sources of radiation may be used to irradiate the inkjet ink composition.

The recording medium may be in an absorbing medium or non-absorbing medium. Examples of recording media include plain paper, vinyl, corrugated cardboard, folding carton, coated inkjet paper, uncoated inkjet paper, wall paper fabrics, kraft paper

Cellulose, coated paper, cotton, PET banner, PET canvas, PET film, PET mesh, PP film, PVC banner, PVC film, PVC mesh, SA PET, SA PP, SAV, blockout soft signage, frontlit soft signage, backlit soft signage, blockout soft signage, piled soft signage, structured Soft Signage, reflective Sign, heavy PVC film, SA PU and SAV.

Further examples of recording media include polyalkylene media, such as polyethylene or polyprolylene, for example fluted PP; polystyrene media, PMMA films, PMMA rigids, polycarbonate rigids, dibond media, polyester films, such as LFM450 and IJM778, corrugated carton, honeycomb, katzboard, solid bleached boards, aluminium compound material, forex, glass, high pressure laminate, PET-G, ACM, Plywood and wood.

In an embodiment, a time interval between jetting droplets of the ink composition and curing the ink composition is at least 20 seconds.

The time interval between applying the radiation-curable ink and curing the radiation-curable ink may be at least 20 seconds, preferably at least 40 seconds. In case the time interval between applying the radiation-curable gel ink and curing the radiation-curable gel ink is less than 20 seconds, an image may be formed comprising a plurality of layers, without intermediate curing of the ink. In case the time interval between applying the ink and curing the ink is at least 20 seconds, the ink may spread sufficiently, resulting in good image quality.

The ink composition is a gelling ink composition. When using a gelling ink composition, no color bleed may occur, even if the time interval between jetting droplets of the ink composition and curing the ink composition is 20 seconds or more.

Optionally, the ink can be pinned (i.e. partially cured) shortly after being applied onto the recording medium and afterwards, such as a time interval in the range of from 10s - 100s, fully cured.

In an embodiment, the ink is applied in multiple layers and the layers are deposited before the radiation-curable ink is irradiated.

A printed image may comprise a plurality of layers of ink. Ink may be applied in a plurality of swaths, wherein a new swath of ink is applied onto a previously applied swath of ink. The swaths, or layers may together form an image. All ink layers may be applied onto the recording medium before the ink is cured by irradiating the ink. The use of radiation-curable gel ink allows to apply relatively thick layers onto a recording medium, before curing the ink. Thick layers of ink are difficult to cure, as the radiation needs to penetrate through a thick layer of ink to cure the entire layer, including the ink-

recording medium interface, the bulk of the layer and the ink-air interface. The present invention allows to efficiently cure the entire layer of ink and creating prints having good print quality, including good surface cure.

In an aspect of the invention a printer is provided, the printer comprising:

a. an ink applicator configured to apply a radiation-curable ink composition according to the present invention onto a recording medium;
b. a media support for supporting a recording medium;
c. a curing unit; and
d. a controller configured to control the ink-jet printer to perform a method in accordance with the present invention.

A printer is also referred to as printing apparatus. The printer may be configured to in printing operation apply a radiation-curable ink. Suitable types of radiation-curable ink including radiation-curable inkjet inks and radiation-curable gelling inkjet inks are known in the art. Preferably, the printer may be an inkjet printer, configured to apply ink onto the recording medium by jetting droplets of ink onto the recording medium in a predetermined pattern to form an image.

The printing apparatus comprises an ink applicator. The ink applicator may be configured to in operation apply a predetermined pattern of a radiation-curable ink on a recording medium.

The ink applicator may comprise at least one inkjet print head configured to in operation jet ink onto the recording medium. The print head may be for example a thermal inkjet print head or a piezo electric inkjet print head. The printer may comprise a plurality of inkjet print heads. One type or color of ink may be used to form the image, but alternatively more than one type and/or color of ink may be used. A Cyan, a Magenta, a Yellow and a blacK ink may be used to form the image. In addition, one or more of a white ink, brown ink, grey ink, light magenta, light cyan, red, green, orange, purple ink may be used. Further, one or more of a primer composition, an overcoat composition and a metallic ink may be used. The print unit may be a page-wide print unit or may be a scanning print unit. A scanning print unit may be configured to in operation move in reciprocation in a scanning direction. The scanning direction may be perpendicular to a medium transport direction.

The printer further comprises a media support. The media support may be configured to

in operation support the recording medium. Optionally, the recording medium may be moved in a medium transport direction. The medium support may comprise a flat table. Optionally, the medium support may comprise an endless belt. The medium support may comprise holes for applying an underpressure. Applying an underpressure may fix the recording medium to the medium support.
Optionally, the printing apparatus may comprise a medium transport unit. The medium transport unit may be configured to in operation move the recording medium relative to the printer in the medium transport direction.

The printer further comprises a curing unit. The curing unit is configured to in operation irradiate a recording medium provided with a radiation-curable ink. By irradiating the radiation-curable ink, a chemical reaction may occur in the radiation-curable ink, which may result in curing or pre-curing of the fluid. The curing unit may be a scanning curing unit. Alternatively, the curing unit may be a page-wide curing unit.
In an embodiment, one or more lamps may be provided in proximity of the ink applicator, for example on a print carriage. The one or more lamps may be provided at a lateral edge, in the main scanning direction, of the print head carriage. The one or more lamps provided on the print carriage may be pinning lamps for preliminary curing the ink provided onto the recording medium.

The printer further comprises a controller. The controller may control the printer to perform a method in accordance with the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:
Fig. 1 is a schematic perspective view of a first example of a printing system according to the present invention in a first printing mode;
Fig. 2 is a schematic perspective view of a second example of a printing system according to the present invention in a second printing mode;
Fig. 3 is a schematic diagram of a control unit of a reprographic system according to Fig. 1 or 2.

In the drawings, same reference numerals refer to same elements.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described with reference to the accompanying drawings, wherein the same reference numerals have been used to identify the same or similar elements throughout the several views.

Printing system

Fig. 1 shows a printing apparatus. A printing apparatus is also known as a printer. The printing apparatus 1 comprises an scanning printing unit 7 for printing on a recording medium 15. The recording medium 15 in Fig. 1 is a relatively rigid substrate, such as a panel. The recording medium 15 is supplied from a media input unit 14, which may be configured for storing a plurality of such print media 15 and supplying these to the printer 1. The printer 1 comprises a medium support 4. Printer 1 may further comprise transport means for receiving and transporting the recording medium 15 along the scanning printing unit 7. In Fig. 1, the medium support is embodied as an endless belt 4. The endless belt is an endless transport belt 4 supported on a plurality of support rollers 3A, 3B, 3C. At least one of the support rollers 3A, 3B, 3C is provided with driving means for moving the belt 4. The belt 4 is therefore configured to support and transport the recording medium. Additionally, one or more one of the support rollers 3A, 3B, 3C may be configured to be moved and/or tilted to adjust and control the lateral position of the belt 4. The scanning printing unit 7may be provided with a sensor 8, such as a CCD camera, to determine the relative position of belt 4 and/or the recording medium 15. Data from said sensor 8 may be applied to control the position of the belt 4 and/or the recording medium 15. The belt 4 is further provided with through-holes and a suction box 5 in connection with a suction source (not shown), such that an underpressure may be applied to the recording medium 15 via the through-holes in the belt 4. The underpressure adheres the recording medium 15 flatly to the belt 4 and prevents displacement of the recording medium 15 with respect to the belt 4. Due to this holding the belt 4 is able to transport the recording medium 15. It will be appreciated that other suitable transport means, such as rollers, steppers, etc, may alternatively be applied. The recording medium 15 may be transported stepwise and/or in continuous movement. The scanning printing unit 7 is configured to translate along a first guide beam 6 in a scanning direction. The scanning direction is perpendicular to the direction in which the print medium is transported by the belt 4. The scanning printing unit 7 holds a plurality of print heads (not shown), which are configured to jet a plurality of different marking materials (different colors of ink, primers, coatings, etc.) on the recording medium 15.

Each marking material for use in the scanning printing unit 7 is stored in one of a plurality of containers arranged in fluid connection with the respective print heads for supplying marking material to said print heads to print an image on the recording medium 15.

The application of the marking material, such as the radiation-curable ink from the printing units is performed in accordance with data provided in the respective print job. The printing unit may comprise one or more inkjet print heads. The timing by which the droplets of marking material are released from the one or more print heads determines their position on the recording medium 15. The timing may be adjusted based on the position of the scanning printing unit 7 along the first guide beam 6. The above mentioned sensor 8 may therein be applied to determine the relative position and/or velocity of the scanning printing unit 7 with respect to the recording medium 15. Based upon data from the sensor 8, the release timing of the marking material may be adjusted.

Upon ejection of the marking material, some marking material may be spilled and stay on a nozzle surface of the print heads. The marking material present on the nozzle surface, may negatively influence the ejection of droplets and the placement of these droplets on the recording medium 15. Therefore, it may be advantageous to remove excess of marking material from the nozzle surface. The excess of marking material may be removed for example by wiping with a wiper and/or by application of a suitable anti-wetting property of the surface, e.g. provided by a coating.

The marking materials may require treatment to properly fixate them on the print medium. Thereto, a fixation unit is provided downstream of the scanning printing unit 7. The fixation unit may emit radiation to facilitate the marking material fixation process. In the example of Fig. 1, the fixation unit is scanning curing array 10.

The scanning curing unit comprises at least one radiation emitting unit (not shown). In operation, the curing unit 10 is moved in reciprocation in the scanning direction along guide rail 17. Further, the inkjet printing assembly 7 may be provided with a further fixation unit on the same carriage which holds the print heads. This further fixation unit can be used to (partially) cure and/or harden the marking materials, independent of or interaction with the fixation unit 10.

The scanning curing array 10 is configured to in operation emit radiation of certain frequencies, which interacts with the marking materials, for example UV light in case of UV-curable inks. Optionally (not shown), the scanning printing unit 7 may be provided with a further fixation unit on the same carriage which holds the print heads. This further

fixation unit can be used to (partially) cure and/or harden the marking materials, independent of or interaction with the scanning curing array 10.

After printing and fixation, the recording medium 15 is transported to a receiving unit (not shown). The receiving unit may comprise a take-up roller for winding up the recording medium 15, a receiving tray for supporting sheets of recording medium 15, or a rigid media handler, similar to the media input unit 14. Optionally, the receiving unit may comprise processing means for processing the medium after printing, e.g. a post-treatment device such as a coater, a folder, a cutter, or a puncher.

Printing apparatus 1 furthermore comprises a user interface 11 for receiving print jobs and optionally for manipulating print jobs. The local user interface unit 11 is integrated to the print engine and may comprise a display unit and a control panel. Alternatively, the control panel may be integrated in the display unit, for example in the form of a touch-screen control panel. The local user interface unit 11 is connected to a control unit 12 connected to the printer 1. The control unit 12, for example a computer, comprises a processor adapted to issue commands to the printer 1, for example for controlling the print process. The printer 1 may optionally be connected to a network. The connection to the network can be via cable or wireless. The printer 1 may receive printing jobs via the network. Further, optionally, the control unit 12 of the printer 1 may be provided with an input port, such as a USB port, so printing jobs may be sent to the printer 1 via this input port.

Hybrid printing system

The printer 1 in Fig. 1 is a so-called hybrid printer, capable of handling both flexible media and rigid substrates. In Fig. 1, the printer 1 operates in a first print mode, wherein the printer 1 is configured for transporting rigid substrates, such as the recording medium 15. Such rigid print media 15 may be panels, for example panels for doors or walls, corrugated media, plates formed of plastic or metal, etc. To handle these rigid print media 15, the printer 1 in Fig. 1 is configured with a substantially linear transport path: from the media input device 14, the recording medium 15 moves forward along the scanning printing unit 7 at a at substantially constant height. The media input unit 14 and the receiving unit are positioned at the level of the medium support surface of the belt 4. In Fig. 2, a flexible web medium 16 is supplied to the printer 1, which web medium 16 may be composed of e.g. paper, label stock, coated paper, plastic or textile. The web medium 16 is supplied from the input roller 2A and extends across the belt 4 to

the take-up roller 2B, where the web medium 16 is re-wound. The printer 1 is configured to swiftly and efficiently switch between print modes.

Further, the printer 1 shown in Fig.2 comprises a page-wide curing array 10. The page-wide curing array extends in the main scanning direction. The page-wide curing array does not move in operation in the main scanning direction. The page-wide array may move in the direction of medium transport, which is a direction perpendicular to the scanning direction.

Control

An embodiment of the control unit 12 is in more detail presented in Fig. 3. As shown in Fig. 3, the control unit 12 comprises a Central Processing Unit (CPU) 31, a Graphical Processor Unit (GPU) 32, a Random Access Memory (RAM) 33, a Read Only Memory (ROM) 34, a network unit 36, an interface unit 37, a hard disk (HD) 35 and an image processing unit 39 such as a Raster Image Processor (RIP). The aforementioned units 31 - 37 are interconnected through a bus system 38. However, the control unit 12 may also be a distributed control unit.

The CPU 31 controls the printing system 1 in accordance with control programs stored in the ROM 34 or on the HD 35 and the local user interface panel 11. The CPU 31 also controls the image processing unit 39 and the GPU 32. The ROM 34 stores programs and data such as boot program, set-up program, various set-up data or the like, which are to be read out and executed by the CPU 31. The hard disk 35 is an example of a non-volatile storage unit for storing and saving programs and data which make the CPU 31 execute a print process to be described later. The hard disk 35 also comprises an area for saving the data of externally submitted print jobs. The programs and data on the HD 35 are read out onto the RAM 33 by the CPU 31 as needed. The RAM 33 has an area for temporarily storing the programs and data read out from the ROM 34 and HD 35 by the CPU 31, and a work area which is used by the CPU 31 to execute various processes. The interface unit 37 connects the control unit 12 to the client devices, such as scan device 21 and to the printing system 1. The network unit 36 connects the control unit 12 to the network N and is designed to provide communication with the workstations (not shown) and with other devices 21 reachable via the network N. The image processing unit 39 may be implemented as a software component running on an operation system of the control unit 12 or as a firmware program, for example embodied in a field-programmable gate array (FPGA) or an application-specific integrated circuit (ASIC). The image processing unit 39 has functions for reading, interpreting and

rasterizing the print job data. Said print job data contains image data to be printed (i.e. fonts and graphics that describe the content of the document to be printed, described in a Page Description Language or the like), image processing attributes and print settings.

Experiments and examples

Materials

SR355, SR339C, SR506D, SR351, CN3755 and CN991 were obtained from Arkema, Viscoat #200 was obtained from Osaka Chemical, ITX and EDB were obtained from Rahn, BYK 333 was obtained from BYK, pentaerythritoltetrastearate was obtained from TCI chemicals, BAPO was obtained from Arkema (Lambson), NeoCryl® B-302 was obtained from Covestro, phenothiazine was obtained from Allessa. Cyan pigments were obtained from Sun as dispersions (25 wt% pigments in SR9003) MPI2000 was obtained from Avery. All materials were used as obtained, unless stated otherwise.

SR355 is ditrimethylolpropane tetraacrylate, a tetrafunctional acrylate component with a molecular weight of 482 g/mole.
SR339C is 2-phenoxyethyl acrylate, a monofunctional acrylate having a molecular weigth of 192 g/mole.
SR506D is isobornyl acrylate. It is a monofunctional acrylate having a molecular weigth of 208 g/mole.
SR351 is trimethylolpropane triacrylate. It is a trifunctional acrylate having a molecular weigth of 296 g/mole.
CN3755 is a difunctional acrylated amine with a molecular weight M_W of 800 g/mole.
CN991 is a difunctional aliphatic urethane acrylate oligomer with a molecular weight M_W of 1500 g/mole.
Viscoat #200 is Cyclic Trimethylolpropane Formal Acrylate (CTFA). It is a monofunctional acrylate having a molecular weigth of 200 g/mole.
NeoCryl® B-302 is an inert acrylic resin, wherein M_W = 5000.
ITX is isopropylthioxanthone, which is a photoinitiator.
BAPO is phenylbis(2,4,6-trimethylbenzoyl) phosphineoxide, which is a photoinitiator.
EDB is ethyl 4-(dimethylamino) benzoate, which is a co-initiator.
BYK 333 is a silicone based surfactant.

Pentaerythritoltetrastearate is a gellant.

NeoCryl® B-302 is an inert resin, and is an acrylic resin.

phenothiazine is an inhibitor.

Cyan pigments are used as colorant.

Methods

Printing method

Prints were made on a Colorado 1650 printer. The printer was modified by replacing the scanning cure unit by a page-wide lamp. MPI2000 was used as a recording medium. The temperature of the print surface was controlled at 24ºC.

Ink preparations

Ink compositions **Ex 1** and **CE 1** were prepared by providing the components shown in table 1 in the amount shown in table 1 and mixing the components.

The first ink composition is ink composition **Ex 1**, which is an ink composition according to the present invention.

The second ink composition is ink composition **CE 1**, which is an ink composition not according to the present invention.

Table 1: Ink compositions **Ex 1**and **CE 1**

	Ex 1	**CE 1**
SR355	1,49%	0,29%
Viscoat#200	25,97%	24,36%
SR351	1,37%	0
SR506D	18,53%	17,04%
SR339C	18,53%	17,04%
CN3755	4,92%	4,92%
CN991	0	19,00%
ITX	3,75%	3,75%
BAPO	1,00%	1,00%
EDB	4,25%	4,25%
BYK333	0,50%	0,50%
Phenothiazine	0,07%	0,07%

NeoCryl® B-302	11,86%	0
Pentaerythritoltetrastearate	1,00%	1,00%
Pigment dispersion	5.69	5.69
dispersant	1.09%	1.09%
Total	100	100

For the ink compositions **Ex1** and **CE1**, the DBD and the average functionality were calculated.

Table 2: DBD and average F of **Ex1**

Components	**$(wt\%)_i$**	$(m_w)_i$	f_i	**$((wt\%)_i/(m_w)_i)*1000$**	**$(f_i*(wt\%)_i/(m_w)_i)*1000$**
SR355	1,49%	482	4	0,031	0,124
Viscoat#200	25,97%	200	1	1,298	1,298
SR351	1,37%	296	3	0,046	0,138
SR506D	18,53%	208	1	0,891	0,891
SR339C	18,53%	192	1	0,965	0,965
CN3755	4,92%	800	2	0,062	0,123
SR9003	4,27%	328	2	0,130	0,260
NeoCryl® B-302	11,86%	5000	0	0,024	0,000
				DBD	**3,799**
sum	86,92%			Average F	**1.102**

Table 3: DBD and average F of **CE1**

Components	**$(wt\%)_i$**	$(m_w)_i$	f_i	**$((wt\%)_i/(m_w)_i)*1000$**	**$(f_i*(wt\%)_i/(m_w)_i)*1000$**
SR355	0,29%	482	4	0,006	0,024
Viscoat#200	24,36%	200	1	1,218	1,218
SR506D	17,04%	208	1	0,819	0,819
SR339C	17,04%	192	1	0,888	0,888
CN991	19,00%	1500	2	0,127	0,253
CN3755	4,92%	800	2	0,062	0,123
SR9003	4,27%	328	2	0,130	0,260

NeoCryl® B-302	0	5000	0	0	0,000
				DBD	**3,596**
sum	86,92%			Average F	**1,104**

Detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually and appropriately detailed structure. In particular, features presented and described in separate dependent claims may be applied in combination and any combination of such claims are herewith disclosed. Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention. The terms “a” or “an”, as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language). The term coupled, as used herein, is defined as connected, although not necessarily directly.

CLAIMS

1. Radiation-curable gelling ink composition, the radiation-curable gelling ink composition comprising a radiation-curable matrix and one or more gellants, the radiation-curable matrix consisting of one or more radiation-curable components and one or more inert resins, wherein the radiation-curable matrix has an double bond density (DBD) and an average functionality (average F), the double bond density (DBD) being defined as:

$$DBD = \frac{\sum_{i=1}^{n}\left(f_i * \frac{(wt\%)_i}{(m_w)_i} * 1000\right)}{100}$$

and the average functionality being defined as:

$$Average\ F = \frac{\sum_{i=1}^{n}\left(f_i * \frac{(wt\%)_i}{(m_w)_i} * 1000\right)}{\sum_{i=1}^{n}\left(\frac{(wt\%)_i}{(m_w)_i} * 1000\right)}$$

wherein f_i is the functionality of the individual components in the radiation-curable matrix; $(wt\%)_i$ is the weight percentage of the individual components, with respect to the total weight of the radiation-curable gelling ink composition, in which the individual components is present; and $(m_w)_i$ is the molecular weight of the individual components in the radiation-curable matrix, and
wherein the DBD is higher than 3 and the average functionality is in the range of from 0.9 to 1.25.

2. Radiation-curable gelling ink composition according to claim 1, wherein the inert resin is present in an amount of from 5 wt% to 30 wt% based on the total weight of the radiation-curable gelling ink composition.

3. Radiation-curable gelling ink composition according to claim 1 or 2, wherein the inert resin has a molecular weight M_W in the range of from 1000 g/mole to 75000 g/mole.

4. Radiation-curable gelling ink composition according to any of the preceding claims, wherein the one or more radiation-curable components are present in an amount of

from 40 wt% to 90 wt% based on the total weight of the radiation-curable gelling ink composition.

5. Radiation-curable gelling ink composition according to any of the preceding claims, wherein the one or more monofunctional radiation-curable components are present in an amount of from 35 wt% to 80 wt% based on the total weight of the radiation-curable gelling ink composition.

6. Radiation-curable gelling ink composition according to any of the preceding claims, wherein the radiation-curable gelling ink composition further comprises a colorant.

7. Inkset comprising a first radiation-curable gelling ink composition and a second radiation-curable gelling ink composition, the first radiation curable ink composition being an ink composition according to any of the claims 1-6 and comprising a first colorant, the second radiation curable ink composition being an ink composition according to any of the claims 1-6 and comprising a second colorant, different from the first colorant.

8. Method for preparing an ink composition according to any of the claims 1 to 6, the method comprising the steps of:
    a. providing one or more one or more radiation-curable components;
    b. providing one or more gelling agents;
    c. providing one or more inert resins;
    d. mixing the one or more gelling agents, the one or more radiation-curable components, and the one or more inert resins.

9. Method for printing an image onto a recording medium, the method comprising the steps of:
    a. jetting droplets of a radiation-curable inkjet ink composition according to any of claims 1-6 onto the recording medium;
    b. curing the radiation-curable inkjet ink composition by irradiating the ink composition using UV radiation.

10. Method according to claim 9, wherein a time interval between jetting droplets of the ink composition and curing the ink composition is at least 20 seconds.

11. Printer, the printer comprising:

a. an ink applicator configured to apply a radiation-curable ink composition according to any of the claims 1-6 onto a recording medium;

b. a media support for supporting a recording medium;

c. a curing unit; and

d. a controller configured to control the ink-jet printer to perform a method according to claim 9 or 10.