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(71) Applicant: **LEXMARK INTERNATIONAL, INC.**
Lexington, Kentucky 40511 (US)

(72) Inventors:
• **Decoste, Charles Leonard, Jr.**
Richmond, Kentucky 40475 (US)

• **Elbert, Donald Leo**
Lexington, Kentucky 40502 (US)
• **Beach, Bradley Leonard**
Lexington, Kentucky 40505 (US)

(74) Representative: **Matthews, Derek Peter et al**
Frank B. Dehn & Co.,
European Patent Attorneys,
179 Queen Victoria Street
London EC4V 4EL (GB)

(54) **Ink reservoir for ink jet printer**

(57) An ink reservoir for use in an ink jet printer cartridge is disclosed. This ink reservoir maintains effective flow of the ink to the print head but contains only minimal levels of nonvolatile residues. The ink reservoir utilizes

a nonfelted reticulated foam having from 65 to 110 pores per inch (ppi, equivalent to 25 to 45 pores per cm), preferably from 88 to 98 ppi (35 to 38 pores per cm), with a compression ratio of from 1.5 to 6.5, preferably from 2.0 to 4.0.

EP 0 832 750 A2

Description

TECHNICAL FIELD

The present invention relates to ink cartridges which are used in ink jet printers. Particularly, it relates to the reservoirs which hold and feed out the ink in those cartridges during the printing process.

BACKGROUND OF THE INVENTION

Ink jet heads (or ink jet cartridges) are well known in the art. They provide the means by which an ink jet printer holds and meters out the appropriate amount of ink, when needed, to ensure clear, smudge-free printing. Such cartridges usually consist of an energy generating portion which forms droplets of the ink and an ink tank which supplies ink to the energy generating portion. Generally, in such ink cartridges, the ink is absorbed and held in place by a porous material compressed and encased in an ink tank. The ink held by the porous material is pulled out by the capillary force of a nozzle as it is required at the ink ejection portion of the ink jet head.

Polyurethane foams are the best known reservoir materials for use in ink jet cartridges. U.S. Patent 4,306,245, Kasugayama, et al., issued December 15, 1981, discloses a specific use range of the ink absorbing material in an ink jet recording apparatus. Further, U.S. Patent 4,790,409, Deaver, issued December 13, 1988, and U.S. Patent 4,824,887, Aycock, et al., issued April 25, 1989, teach the fabrication of a commercial foam into a size suitable for use in an ink cartridge, as well as a process for washing out nonvolatile matter contained in that material.

The presence of nonvolatile materials (also known as nonvolatile residue, or NVR) in the foam reservoir can cause significant problems in the printing process. Typically, the foam used for ink delivery in an ink jet cartridge contains levels of nonvolatile residue in the range of from about 0.5% to greater than 3% by weight of the foam. This residue consists of low molecular weight urethanes resulting from the chain termination during formation of the foam and from degradation of urethane linkages during manufacture of the foam, as well as remnants of surfactant used as an ingredient in the foam formulation. During use of the printer, such residues can deposit on the plate containing the nozzles thereby causing clogging and other operational failures.

A typical prior art ink reservoir might comprise a polyether urethane foam, having a pore size of 70 pores per inch (ppi, about 25 pores per cm), which is reticulated to obtain open cells. Then, the material is felted by applying heat and compression in order to provide the foam with its ink holding and metering capabilities by reducing its volume to between 1/3 and 1/6 of the unfelted volume. Following that, the felted foam is cut into individual pieces to be put in the ink reservoir. However,

the felting process also results in high levels of undesirable nonvolatile residue in the foam. It is possible to clean nonvolatile residues out of the foam, but this adds expense and extra steps to the manufacturing process. An example of such a procedure is found in U.S. Patent 4,824,487, Heffernan, issued April 25, 1989, which discloses a specific solvent process for removing residue from the foam. Another way of minimizing nonvolatile residues is disclosed in U.S. Patent 5,572,876, issued October 8, 1996, which discloses a method for felting open cell foams under reduced moisture conditions in order to provide minimized residues of low volatile materials. While these methods are effective in achieving their intended purpose, it would be useful to be able to minimize the nonvolatile residues without having to add additional manufacturing steps or process controls.

Of course, one could consider using nonfelted foams in the ink reservoir since it is the felting process which forms much of the nonvolatile residues. However, such nonfelted foams tend to be too large to fit into conventional ink reservoirs and have insufficient back pressure to effectively hold the ink. This is especially true with low viscosity inks (i.e., those having a viscosity of less than about 2 centipoise). The net result is a phenomenon called drooling wherein the ink dribbles out of the ink reservoir during the printing process, causing smudging and fouling of the printing apparatus.

The purpose of the present invention, therefore, is to provide foam reservoirs for use in ink jet printer cartridges which minimize the presence of nonvolatile residues while providing sufficient ink feed to the printer for effective printing without permitting ink drooling. It has been found that by using as an ink reservoir a reticulated nonfelted foam having a relatively small pore size (i.e., a relatively large number of pores per inch) and which is compressed to a specific compression ratio, this object can be achieved. In addition, since it eliminates felting and residue clean-up steps, the present invention accomplishes this object in a very cost effective manner.

U.S. Patent 2,961,710, Stark, issued November 29, 1960, describes a process for producing expanded urethane foam materials used as filters. The materials produced are reticulated open celled foams; nonvolatile residues do not appear to be an issue considered in this process.

U.S. Patent 3,978,855, McRae, et al., issued September 7, 1976, describes an open celled polyurethane foam surgical dressing made by compressing (under heat) one face of the foam to form small size pores and then applying a wetting agent (surfactant) to that face.

U.S. Patent 4,454,248, Pollock, et al., issued June 12, 1984, describes a strong, nonresilient foam having macroscopic cells. In producing these foams, a partially cured foamed resin is softened and compressed causing the cell walls to rupture, forming an open celled structure. The foam is then reexpanded and given its final cure. A filler, such as carbon black, may be added to the foam prior to the final curing step.

U.S. Patent Re.32,032, Pettingell, issued November 19, 1985, describes a method of densifying open celled polyurethane foams (i.e., felting). In this process, heated air is circulated through the foam which is then compressed through rollers and is immediately cooled.

U.S. Patent 5,025,271, Baker, et al., issued June 18, 1991, describes conventional thermal ink jet print cartridges which include a foam material as an ink reservoir.

U.S. Patent 5,104,908, Allred, et al., issued April 14, 1992, describes a partially cured polychloroprene foam which may be formed into intricate shapes for use in printing. A felting process is used to provide the final cure for these foams.

U.S. Patent 5,182,579, Haruta, et al., issued January 26, 1993, describes an ink tank encasing an absorbent member for use in an ink jet printer. The patent specifically defines the relationship required between the compression ratio and the pore size of the foam. The patent teaches that the compression may be achieved by felting, but also may be achieved by compressing the foam into the cartridge. The patent states that the foam should have a pore size of no greater than 60 ppi (about 25 pores per cm) and, in fact, teaches away from foams having smaller pore sizes (i.e., higher pore densities).

EP-A-0 803 363 describes ink cartridges using non-felted foams which are especially adapted to act as reservoirs for high viscosity (pigmented) inks. The use of compressed foams in the cartridge is not disclosed.

SUMMARY OF THE INVENTION

The present invention relates to printer ink cartridges which contain a non-felted reticulated foam having from about 65 to about 110 pores per inch (about 25 to 45 pores per cm), preferably from about 88 to about 98 pores per inch (about 35 to 38 pores per cm), and a compression ratio of from about 1.5 to about 6.5, preferably from about 2 to about 4. Preferred foams for use in present invention are urethane foams, particularly polyether polyurethane foams. The foams contain very low levels (e.g., less than about 1.5%) of nonvolatile residue. Since the foam is not felted and, in addition, only about 50% (by weight) as much foam is used in the ink reservoir (when compared to conventional ink cartridges), the nonvolatile residue content is reduced by 50% or more on a weight basis or to an equivalent of 0.75% compared to felted foam (weight adjusted basis).

All percentages and ratios described herein are "by weight" unless otherwise specified.

DETAILED DESCRIPTION OF THE INVENTION

Ink jet cartridges are well known in the printer art. For example, they are described in detail in U.S. Patent 5,182,579, Haruta, et al., issued January 26, 1993, and U.S. Patent 5,025,271, Baker, et al., issued June 18, 1991. The portion of the cartridge to which the present

invention relates is the ink tank and particularly the ink reservoir in the ink tank. This portion of the cartridge holds the ink before it is formed into droplets and ejected onto the page in the appropriate pattern during the printing process. The reservoir actually holds the ink but in doing so a very careful balance is required. If the force holding the ink in the reservoir is too great, the ink won't feed and the printing either won't occur or will be too light. If the force holding the ink is not great enough, the ink will drool out of the reservoir fouling the printer and giving a short printer cartridge life.

Generally, in the prior art, the material used in forming the ink reservoir (ink absorbent members) is a reticulated felted foam. However, as discussed above, the felting process results in too high a level of nonvolatile residue for effective printer use. The present invention solves this problem by providing an ink reservoir which effectively holds the ink and meters it out at the appropriate rate but, since it is not felted, does not include high levels of nonvolatile residue.

Any open celled foam material conventionally used in ink reservoirs may be used in the present invention. Urethane foams and formaldehyde foams are preferred materials, with polyether polyurethane foams being particularly preferred. An example of a foam which may be used in the present invention is commercially available from Foamex, Eddystone, Pennsylvania and is a reticulated unfelted polyether polyurethane foam having a pore size of about 93 ppi (about 36 pores per cm).

The ink absorbent member is preferably made from a polyether-type polyurethane foam in the form of a polymeric, elastic porous material having continuous foam cells. The ink absorbent member can be prepared by conducting the reaction of, for example, polyether polyols and toluene diisocyanate as starting materials together with an additive such as a silicon-based surfactant and catalysts, according to conventional processes, thereby forming the foamed reaction product having the desired porosity and density. The resulting foam is then reticulated (i.e., a gas explosion is used to blow out the cell faces) making an open cell foam. The foam may then be cut to the desired shape and size for use in the present invention. There may be impurities, such as unreacted starting materials, in the foam produced; these may be partially removed by washing the foam with organic polar solvents which are not capable of reacting with the absorbent material. However, since the foam is not subjected to a felting step, the level of nonvolatile residue in the foam material is relatively low and does not usually require a separate removal step in order to be used in the present invention. The ink absorbent materials utilized in the present invention generally have low levels of nonvolatile residue, typically no greater than about 1.5 % nonvolatile residue, and preferably no greater than about 1.0% nonvolatile residue. The amount and identity of the surfactant utilized in the synthesis reaction, as well as the water level used and the type and degree of mechanical mixing used, affects

the pore size and density of the finished foam product. Thus, the reaction conditions can be manipulated, as would be recognized by one of ordinary skill in the art, to form a foam having optimized conditions for use in the present invention.

In contrast to the ink reservoir materials utilized in the prior art, the foams utilized in the present invention contain a relatively high pore density (i.e., a relatively small pore size). The conventional thinking was that such high pore density, small pore diameter foams would provide a level of capillary action which was so high so as to hold the ink tightly and not feed the ink effectively to the print head. See, for example, U.S. Patent 5,182,579, Haruta, et al., issued January 26, 1993, which states that the pore density in the foams of an ink reservoir must be no greater than 60 ppi (about 25 pores per cm) and preferably are significantly less than that (i.e., 3540 ppi, about 15 pores per cm). It has now surprisingly been found that high pore densities, when used in a foam having a specifically defined compression ratio, provide sufficient capillary action so as to prevent ink drool while not providing so much capillary action that the ink does not feed effectively into the print head. The foams utilized in the present invention have a pore density of from about 65 to about 110 pores per inch (ppi, about 25 to 45 pores per cm), preferably from about 75 to about 102 ppi (about 30 to 40 pores per cm), more preferably from about 84 to about 102 ppi (about 33 to 40 pores per cm), more preferably from about 88 to about 98 ppi (about 35 to 38 pores per cm), and most preferably about 93 ppi (about 36 pores per cm). Preferred foams have a pore density of greater than about 90 ppi (about 35 pores per cm) and up to about 98 ppi (about 38 pores per cm). If the pore density of the foam is too low, it provides insufficient back pressure and ink drooling occurs. If the pore density is too high, the foam provides too much back pressure and there is insufficient ink feed. Of course, the foams should be fashioned so that the size of the cells is essentially uniform throughout the foam material so that the ink feed will be uniform at all points in the reservoir. The densities of the foams themselves generally range from about .015 to about .040 g/cm³, preferably from about .026 to about .038 g/cm³.

The piece of foam used for the reservoir is cut larger than the size of the ink tank in the cartridge body into which it fits. As a result, the act of placing the foam into the cartridge body acts to compress the foam. When it is in place, the foam reservoir must fill the ink tank and the cartridge body completely and with no wrinkling or channeling, otherwise the flow of the ink out of the reservoir will not be uniform. A method for defining the compression of the ink reservoir is the compression ratio (R) which is the ratio of the apparent volume of the foam before compression (V_1) to the apparent volume of the foam after compression (V_2). The compression ratio (R) is therefore equal to V_1/V_2 . When utilized in the present invention, the foam reservoir materials should have a

compression ratio in the cartridge body of from about 1.5 to about 6.5, preferably from about 2.0 to about 4.0, most preferably from about 2.4 to about 3.6.

When structuring the ink cartridges of the present invention, the viscosity and surface tension of the ink to be utilized should also be taken into consideration. Viscosity of ink used in ink jet printers typically ranges from about 1 cps to about 5 cps. Dye-based inks tend to be less viscous than pigment inks. Color inks tend to be less viscous than black ink. The viscosity of color ink typically is in the range of from about 1.1 cps to about 2.5 cps and the viscosity of black ink typically is from about 1.3 cps to about 4.5 cps. Inks typically have a surface tension between about 30 and about 65 dynes/cm, with color inks being in the range of from about 30 to about 45 dynes/cm and black inks being from about 45 to about 65 dynes/cm. The surface tension and the viscosity of the ink to be used can have an effect on the optimum pore size and compression ratio to be used in the foam reservoir with that ink. For example, an ink having a higher viscosity does not need to be held by the reservoir as tightly which means that the optimum foam material for the reservoir may have a larger pore size or less compression. Conversely, a less viscous ink may require tighter holding by the ink reservoir in order to prevent drooling and the optimum foam material would be structured to provide such holding. The optimum characteristics of the foam reservoir material for use with ink of a particular viscosity can easily be determined by one of ordinary skill in the art. As a general guideline, ink tanks in ink jet printer cartridge bodies typically have a volume in the range of from about 15 cm³ for color inks to about 60 cm³ for monochromatic inks. However, these sizes can vary widely depending on the particular application involved and are limited only by printer design. The dimensions of the foam reservoir material used with black inks are typically in the range of about 160 cm³, preferably about 64 x 42 x 59 mm. The size of the foam reservoir material used with color inks is typically in the range of about 55 cm³, preferably about 22 x 42 x 59 mm. The present invention is particularly useful for dye-based inks (although it can be used with any type of ink), especially those having viscosities below about 1.5 centipoise. It is especially surprising that non-felted foams can hold such low viscosity inks effectively.

The following examples are intended to illustrate the ink reservoirs of the present invention, including how to make and use them. These examples are intended to be illustrative only and are not intended to limit the scope of the invention in any way.

EXAMPLE 1

For a black ink having a viscosity of about 1.3 centipoise at 25°C and a surface tension of about 50 dynes/cm, the following pore sizes and compression ratios, as the foam (polyether polyurethane foam) is put into the reservoir, provides a cartridge that prints satis-

factorily, does not exhibit drooling or flooding and provides acceptable print life.

pore size = 88 - 98 ppi (35-38 pores per cm), unfelted
foam density = .026 - .038 g/cm³
foam size/volume = 64 x 42 x 59 mm = 159 cm³
reservoir size/volume = 51 x 38 x 33 mm = 64 cm³
compression ratio = 2.48 (159/64)

EXAMPLE 2

For a color ink having a viscosity of about 1.1 centipoise at 25°C and a surface tension of about 35 dynes/cm, the following pore sizes and compression ratios, as the foam (polyether polyurethane foam) is put into the reservoir, provides a cartridge that prints satisfactorily, does not exhibit drooling or flooding and provides acceptable print life.

pore size = 88 - 98 ppi (35-38 pores per cm), unfelted
foam density = .026 - .038 g/cm³
foam size/volume = 22 x 42 x 59 mm = 55 cm³
reservoir size/volume = 10 x 38 x 48 mm = 18 cm³
compression ratio = 3.1(55/18)

EXAMPLE 3

For a black ink having a viscosity of about 4.5 centipoise at 25°C and a surface tension of about 55 dynes/cm, the following pore sizes and compression ratios, as the foam (polyether polyurethane foam) is put into the reservoir, provides a cartridge that prints satisfactorily, does not exhibit drooling or flooding and provides acceptable print life.

pore size = 65 - 80 ppi (25-32 pores per cm), unfelted
foam density = .026 - .038 g/cm³
foam size/volume = 64 x 42 x 59 mm = 159 cm³
reservoir size/volume = 51 x 38 x 33 mm = 64 cm³
compression ratio = 2.48 (159/64)

Claims

1. A printer ink cartridge which contains a nonfelted reticulated foam having from 65 to 110 pores per inch (25 to 45 pores per cm) and a compression ratio of from about 1.5 to about 6.5.
2. The ink cartridge according to Claim 1 wherein the foam is selected from urethane foams and formaldehyde foams.
3. The ink cartridge according to Claim 1 or Claim 2 wherein the foam contains no more than 1.5% non-

volatile residue.

4. The ink cartridge according to any preceding Claim which is fashioned for use with an ink having a viscosity of 1 cps to 5 cps.
5. The ink cartridge according to any preceding Claim wherein the foam has from 84 to 102 pores per inch (33 to 40 pores per cm).
6. The ink cartridge according to any preceding Claim wherein the foam fills the cartridge ink tank body completely with no wrinkling and no channeling.
7. The ink cartridge according to any preceding Claim wherein the foam has a compression ratio of from 2.0 to 4.0.
8. The ink cartridge according to any preceding Claim wherein the foam contains no more than 1.0% non-volatile residue.
9. The ink cartridge according to any preceding Claim wherein the foam has from 88 to 98 pores per inch (35 to 38 pores per cm).
10. The ink cartridge according to any preceding Claim wherein the foam is a polyether polyurethane foam.
11. The ink cartridge according to Claim 10 wherein the foam has a density of from .015 to .040 g/cm³.
12. The ink cartridge according to any preceding Claim which additionally comprises a dye-based ink releasably held within said non-felted foam.
13. The ink cartridge according to Claim 12 wherein said ink has a viscosity of less than about 1.5 centipoise.