

Description

This invention relates generally to the manufacture of orifice plates for ink jet pens and more particularly to the manufacture of a plastic orifice plate for a thermal ink jet printhead.

In the manufacture of disposable pens for thermal ink jet printing systems, it has been one practice to employ metal electroplating processes to form the outer ink ejection orifice plate of the pen to a desired contoured geometry. This orifice plate is also sometimes referred to as a nozzle plate, and will typically be adhesively secured to and precisely aligned with an underlying thin film resistor (TFR) substrate. In this structure, a plurality of resistive heater elements will normally be aligned with an associated plurality of ink reservoirs from which ink is ejected through orifice openings in the covering orifice plate during an ink jet printing operation. This type of thin film resistor printhead structure is described, for example, in the Hewlett-Packard Journal, Vol. 36, No. 5, May 1985, incorporated herein by reference.

In addition to the above HP Journal disclosure, other types of nickel orifice plates and related electroforming processes are described in U.S. Patent 4,694,308 issued to C.S. Chan et al entitled "Barrier Layer and Orifice Plate for Thermal Ink Jet Printhead Assembly", and in US Patent No. 4 716 423 by C.S. Chan et al entitled "Improved Barrier Layer and Orifice Plate for Thermal Ink Jet Printhead Assembly and Method of Manufacture", filed October 3, 1986. Both the patent and the copending application are assigned to the present assignee and are incorporated herein by reference. In addition to the above disclosures, a related electroforming process for manufacturing a compound bore nickel orifice plate for an ink jet printhead is disclosed and claimed in U.S. Patent No. 4,675,083 issued to James G. Bearss et al on June 23, 1987, also assigned to the present assignee and incorporated herein by reference.

The metal orifice plates disclosed in the above identified references have proven highly acceptable in terms of improving ink ejection efficiency and performance and in reducing ink cavitation wear and ink corrosion, thus increasing the printhead lifetime. However, these metal orifice plates are opaque and thus do not enable one to actually view the fluid dynamics which occur beneath the orifice plate and above the associated thin film resistor substrate during an ink jet printhead testing and evaluation operation.

Accordingly, it is a general object of the present invention to provide a new and improved plastic orifice plate and process for fabricating same wherein preferred orifice geometries and spacings of the types disclosed in the above Chan et al and Bearss et al inventions are preserved.

Another object is to provide a new and improved transparent plastic orifice plate and process for fabricating same wherein one may view the actual fluid dynamics through the orifice plate and occurring above the printhead substrate during printhead testing and evaluation.

Another object is to provide a plastic orifice plate and related process of the type described in which durable and economical orifice plates may be reliably reproduced at high yields.

Another object is to provide a new and improved plastic orifice plate which may or may not be transparent and which is non-corrosive.

A further object is to provide a new and improved plastic orifice plate of the type described in which integral barrier layers may be formed with an outer orifice plate for subsequent attachment to a thin film resistor or equivalent energy generating substrate. Thus the requirement for providing intermediate polymer barrier layers may be eliminated and the overall printhead fabrication cost is reduced.

The above objects and attendant advantages and features of this invention are achieved by the provision of a manufacturing process which includes electroforming a metal die so as to have raised sections of a preferred contoured surface geometry which replicates the desired internal surface geometry of a plastic orifice plate. A plastic preform of a preselected thickness is then brought into physical contact with the metal die in such a manner that the raised sections of the die are punched through the plastic preform to thereby form a plurality of closely spaced and contoured orifice openings therein. When it is desired to view fluid dynamics and the like within the underlying printhead substrate, then one obviously would use a clear transparent plastic preform in the above manufacturing process.

The above summary of this invention will become better understood from the following description of the accompanying drawings.

Figures 1A through 1H illustrate in a sequence of isometric views the various process steps which are carried out in accordance with a preferred embodiment of this invention.

Figures 2A through 2H are cross section views corresponding to Figures 1A-1H and are taken along lines 2-2 of Figure 1A by way of example for one set of figures 1A and 2A.

Referring now to the corresponding isometric and cross section views in Figures 1 and 2, respectively, a stainless steel substrate 10 is coated with a thin layer of photoresist 12 in a well known manner and in accordance with teachings of the above identified Chan et al patent or application. The photoresist 12 is then treated with conventional photolithographic masking, UV exposure and development processes to form

a photoresist mask 14 which is cylindrical in shape as indicated in Figures 1B and 2B.

The masked structure of Figures 1B and 2B is then transferred to a nickel electroforming station wherein a first, surface layer 16 of nickel is formed in the geometry shown in Figure 1C + 2C, including a convergent orifice opening 18 which forms concentrically with the mask 14 as described in further detail in the above identified Chan et al inventions. The use of the circular mask 14 in the manner shown enables the nickel to plate up over the outer edge of the mask and in so doing form the convergent orifice opening 18. However, it will be understood that the single opening 18 is merely representative of a plurality of openings which ultimately correspond to a plurality of orifice openings in the plastic orifice plate manufactured in accordance with the "stamp-out" or "punch-through" process described in more detail below.

The structure in Figures 1C and 2C is then placed in a chemical bath to remove the photoresist mask 14 and then transferred to an oven and heated to about 150 °C for approximately two hours to form a thin nickel oxide layer 20 thereon as shown in Figures 1D and 2D. The latter structure is then removed from the oven and taken again to the nickel electroforming station where another layer 22 of nickel is electroformed to a thickness of approximately 67.2 μm. This second nickel layer 22 is shown in Figures 1E and 2E, and the purpose of the nickel oxide layer 20 is to serve as a separation layer between the first and second nickel platings 16 and 22. The second nickel layer or plating 22 is the die for the subsequent plastic orifice plate-forming step to be described. The nickel die 22 may be easily stripped away from the underlying nickel oxide layer 20 by the use of an adhesive tape applied to both the nickel die 22 and the stainless steel substrate 10 to thereby leave the resultant die structure in the geometry indicated in Figures 1F and 2F.

The nickel die 22 in Figures 1F and 2F is then taken to a heat staker station as indicated in Figures 1G and 2G where it is first placed upon a thin clear transparent plastic disc 24 of approximately 44.8 μm in thickness and then inserted between two pieces of glass 26 and 28. Here a temperature of approximately 200 °C and pressure of approximately 8.27×10^5 N/m² applied to the die 22 and transparent plastic preform 24 so as to cause the contoured mesa section 30 of the die 22 to punch through the thin plastic preform 24 and thereby form the convergently contoured orifice opening 32 in the plastic preform structure shown in Figures 1H and 2H.

The thus formed transparent orifice plate structure 34 shown in Figures 1H and 2H is then placed in a plasma reactor wherein the plastic surface flashing on the plastic orifice plate is removed under the following reactor conditions:

gases = CF₄ and O₂
 power = 200 watts,
 pressure = 93.3 N/m²

and

time = 2 minutes.

This latter procedure will remove approximately 2.24 μm of plastic flashing material from the surface of the plastic orifice plate 34, thereby leaving a clean circular edge 36 as the output edge of the convergent orifice opening 32.

Although the clear plastic preform 24 may be easily obtained through commercial channels, this transparent substrate material was made as follows during the actual reduction to practice of this invention and therefore represents a part of the presently known best mode for carrying out the invention. First, a polycarbonate disc was provided and cut into cubic pellets of approximately 2.8mm side length. Then the pellets were sandwiched between two glass plates and heated to approximately 200 °C and under an applied pressure of 3.45×10^5 N/m² for about 2 minutes. This initial process yielded polycarbonate discs of 268.8 μm in thickness and of about 11.2 mm in diameter.

Next, the above discs were again placed between two glass plates (not shown) which were supported by 2 mm metal substrates (not shown) to control the ultimate preform thickness. Then a temperature of approximately 200 °C and pressure of approximately 6.89×10^5 N/m² were applied to these discs for about 2 minutes to thereby yield the final plastic preforms 24 of about 44.8 μm in thickness.

It will of course be understood that the above description of the formation of a single orifice 32 is only one of many orifices (not shown) which will be simultaneously formed in the transparent orifice plate in accordance with the number, geometry and spacing of a plurality of mesa-like sections 30 on the die 22. Thus, the present invention obviously extends to the formation of either one or a plurality of orifices 32 arranged in any desired geometry.

Additionally, the present invention is not limited to the formation of only single step convergent nozzles and may instead employ either the compound bore geometry approach disclosed in the above Bearss et al U.S. Patent 4675083 or alternatively the double layer nickel geometry disclosed in the above identified Chan et al inventions in forming the die 22 or in any other preferable geometry. When using the double layer nickel process to make the nickel die 22, the mesa section 30 would become a stepped double layer mesa section which could then be used to form an integral multi-layer plastic barrier layer and plastic orifice plate structure similar to the metal barrier layer and metal orifice plate structure described in the first two above identified Chan et al inventions. In this latter alternative embodiment, the creation of the integral plastic barrier layer and orifice plate structure would make possible the elimination of well known polymer barrier layers of the prior art, such as barrier materials known in the art as RISTON and VACREL which are tradenames of the DuPont Company.

The following table of dimensions is given by way of example only:

Table

Layer	Thickness (μm)	Diameter of Orifice (μm)	Center-to-Center Orifice Spacing (μm)
16	44.8	44.8	150.1
20	0.1	N/A	150.1
22	44.8	44.8	150.1
34	44.8	44.8	150.1

Although the present invention is primarily directed to the processing of plastic transparent non-metallic orifice plate preforms, it is not so limited and may be used in processing any preform material which lends itself to the "punch through" die stamping operation disclosed and claimed herein.

Claims

1. A process for forming an orifice plate for an ink jet printhead which comprises:
 - a) providing a metal die having raised contoured convergent mesa-shaped sections therein with predefined center-to-center spacings which define desired corresponding center-to-center spacings of orifice openings in an ink jet orifice plate.
 - b) bringing said die into physical contact with a preform of a preselected material and thickness so that said raised sections of said die punch through said preform and thereby form contoured convergent orifice geometries therein, and
 - c) removing said preform from said die and exposing said preform to a plasma reaction to remove flashing from the punched-formed orifice openings therein.
2. A process for forming convergent orifices in a thin layer to form an orifice plate which comprises the steps of:
 - a) electrodepositing a first metal layer on a substrate having a plurality of protectively masked sections thereon to leave openings in said first metal layer concentric with said masked sections.
 - b) forming a second metal layer on said first metal layer and having smoothly curved convergently contoured mesas therein extending into openings in said first metal layer to form a metal die.
 - c) separating said first and second metal layers, and
 - d) using said second metal layer defining said metal die to stamp out openings in a thin layer of a selected material to form convergent orifices therein.
3. The process defined in claim 2 wherein said selected material is a plastic.
4. The process defined in claim 2 wherein said selected material is a transparent plastic.



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 - c) separating said first and second metal layers, and
 - d) using said second metal layer defining said metal die to stamp out openings in a thin layer of a selected material to form convergent orifices therein.
3. The process defined in claim 2 wherein said selected material is a plastic.
4. The process defined in claim 2 wherein said selected material is a transparent plastic.



Patentansprüche

1. Verfahren zum Bilden einer Düsenplatte für einen Tintenstrahldruckkopf, bei dem
 - a) ein Metallstempel mit erhabenen, profilierten; konvergenten tafelbergförmigen Bereichen und mit definierten Mittelpunktsabständen vorgesehen wird, die entsprechende gewünschte Mittelpunktsabstände von Düsenöffnungen in einer Tintenstrahldüsenplatte bestimmen,
 - b) der Stempel in körperlichen Kontakt gebracht wird mit einem Vorformling aus einem so ausgewählten Werkstoff und mit einer solchen Dicke, daß die erhabenen Bereiche des Stempels durch den Vorformling hindurch stanzen und dabei profilierte konvergente Düsengeometrien darin ausbilden, und
 - c) der Vorformling von dem Stempel entfernt und einer Plasmareaktion ausgesetzt wird, um von den durch Stanzen geformten Düsenöffnungen Fehlstellen, wie Grate, zu entfernen.
2. Verfahren zum Bilden konvergenter Düsen in einer Dünnschicht, um eine Düsenplatte zu bilden, mit den Verfahrensschritten:
 - a) elektrochemisches Ablagern einer ersten Metallschicht auf einem Substrat mit mehreren schützend maskierten Bereichen darin, um Öffnungen in der ersten Metallschicht zu lassen, die zu den maskierten Bereichen konzentrisch sind,
 - b) Ausbilden einer zweiten Metallschicht auf der ersten Metallschicht, die gleichmäßig gekrümmte, konvergent profilierte tafelbergförmige Erhebungen aufweist, welche sich in die Öffnungen in der ersten Metallschicht erstrecken, um einen Metallstempel zu bilden,
 - c) Trennen der ersten und der zweiten Metallschicht und
 - d) Verwenden der zweiten Metallschicht, die den Metallstempel definiert, zum Ausstanzen von Öffnungen in einer Dünnschicht aus einem ausgewählten Werkstoff, um konvergente Düsen darin auszubilden.
3. Verfahren nach Anspruch 2, bei dem der ausgewählte Werkstoff ein Kunststoff ist.
4. Verfahren nach Anspruch 2, bei dem der ausgewählte Werkstoff ein transparenter Kunststoff ist.

Revendications

1. Procédé de formage d'une plaque à orifices pour une tête d'impression à jet d'encre qui consiste à :
 - a) prévoir un outil métallique ayant des sections en forme de méssa convergentes profilées en relief possédant des espacements entre centres prédéfinis qui définissent des espacements entre centres désirés des ouvertures d'orifices dans une plaque à orifices à jet d'encre.
 - b) mettre ledit outil en contact physique avec une préforme possédant une matière et une épaisseur présélectionnées de manière que lesdites sections en relief dudit outil poinçonnent ladite préforme en la traversant et y forment de cette façon des géométries d'orifices convergents profilés ; et
 - c) séparer ladite préforme dudit outil et exposer ladite préforme à une réaction au plasma pour éliminer les bavures des ouvertures d'orifices formées par poinçonnage.
2. Procédé de formation d'orifices convergents dans une couche mince, pour former une plaque à orifices, qui comprend les phases consistant à :
 - a) déposer une première couche de métal par électrodéposition sur un substrat portant une pluralité de sections munies d'un masque protecteur pour laisser les ouvertures dans ladite première couche métallique, concentriquement auxdites sections masquées ;
 - b) former une deuxième couche de métal sur ladite première couche de métal, cette deuxième couche présentant des méssa à profil convergent, à courbe douce, qui font saillie dans des ouvertures de ladite première couche de métal pour former un outil métallique ;
 - c) séparer lesdites première et deuxième couches de métal ; et
 - d) utiliser ladite deuxième couche de métal qui définit ledit outil métallique pour matricer les ouvertures dans une couche mince d'une matière choisie pour former des orifices convergents dans cette couche.
3. Procédé selon la revendication 1, dans lequel ladite matière choisie est une matière plastique.



4. Procédé selon la revendication 2, dans lequel ladite matière choisie est une matière plastique transparente.

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