

METHOD OF FABRICATING MICRO-ELECTROMECHANICAL DEVICES WITH PROTECTIVE STRUCTURES

FIELD OF THE INVENTION

This invention relates to the fabrication of devices incorporating micro-electromechanical systems (MEMS). More particularly, the invention relates to a method of fabricating micro-electromechanical devices with protective structures. For the sake of brevity, such a device shall be referred to below as a MEMS device.

CO-PENDING APPLICATIONS

Various methods, systems and apparatus relating to the present invention are disclosed in the following co-pending applications filed by the applicant or assignee of the present invention simultaneously with the present application:

PCT/AU00/00518,	PCT/AU00/00519,	PCT/AU00/00520,	PCT/AU00/00521,
PCT/AU00/00522,	PCT/AU00/00523,	PCT/AU00/00524,	PCT/AU00/00525,
PCT/AU00/00526,	PCT/AU00/00527,	PCT/AU00/00528,	PCT/AU00/00529,
PCT/AU00/00530,	PCT/AU00/00531,	PCT/AU00/00532,	PCT/AU00/00533,
PCT/AU00/00534,	PCT/AU00/00535,	PCT/AU00/00536,	PCT/AU00/00537,
PCT/AU00/00538,	PCT/AU00/00539,	PCT/AU00/00540,	PCT/AU00/00541,
PCT/AU00/00542,	PCT/AU00/00543,	PCT/AU00/00544,	PCT/AU00/00545,
PCT/AU00/00547,	PCT/AU00/00546,	PCT/AU00/00554,	PCT/AU00/00556,
PCT/AU00/00557,	PCT/AU00/00558,	PCT/AU00/00559,	PCT/AU00/00560,
PCT/AU00/00561,	PCT/AU00/00562,	PCT/AU00/00563,	PCT/AU00/00564,
PCT/AU00/00565,	PCT/AU00/00566,	PCT/AU00/00567,	PCT/AU00/00568,
PCT/AU00/00569,	PCT/AU00/00570,	PCT/AU00/00571,	PCT/AU00/00572,
PCT/AU00/00573,	PCT/AU00/00574,	PCT/AU00/00575,	PCT/AU00/00576,
PCT/AU00/00577,	PCT/AU00/00578,	PCT/AU00/00579,	PCT/AU00/00581,
PCT/AU00/00580,	PCT/AU00/00582,	PCT/AU00/00587,	PCT/AU00/00588,
PCT/AU00/00589,	PCT/AU00/00583,	PCT/AU00/00593,	PCT/AU00/00590,
PCT/AU00/00591,	PCT/AU00/00592,	PCT/AU00/00584,	PCT/AU00/00585,
PCT/AU00/00586,	PCT/AU00/00594,	PCT/AU00/00595,	PCT/AU00/00596,
PCT/AU00/00597,	PCT/AU00/00598,	PCT/AU00/00516,	PCT/AU00/00517,
PCT/AU00/00511,	PCT/AU00/00501,	PCT/AU00/00502,	PCT/AU00/00503,
PCT/AU00/00504,	PCT/AU00/00505,	PCT/AU00/00506,	PCT/AU00/00507,
PCT/AU00/00508,	PCT/AU00/00509,	PCT/AU00/00510,	PCT/AU00/00512,
PCT/AU00/00513,	PCT/AU00/00514,	PCT/AU00/00515	

The disclosures of these co-pending applications are incorporated herein by cross-reference.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided a method of fabricating MEMS devices, the method including the steps of:

- applying a protective structure to a front surface of a substrate on which a plurality of spaced MEMS structures is positioned, the protective structure having a body and a plurality of posts extending from the body, the protective structure being applied so that a strut is received between adjacent MEMS structures;

- separating the substrate such that each MEMS structure is positioned on a respective discrete substrate;

- applying a holding means to a back surface of the substrate;

- separating the body such that the protective structure is divided into discrete protective structures, with a MEMS structure being received between pairs of consecutive posts; and

- releasing the back surface from the holding means.

The step of separating the substrate may include the step of etching the substrate from a back surface to the front surface.

The step of applying a holding means to the back surface of the substrate may include the step of applying an adhesive tape to the back surface.

The method may include the step of applying a handling means to the adhesive tape.

The adhesive tape may be released from the back surface by irradiating the adhesive tape with ultra-violet light.

The method may include the step of etching fluid passages through the substrate, from the back surface, so that each MEMS structure is in fluid communication with a respective fluid passage.

According to a second aspect of the present invention there is provided a method of fabricating MEMS devices, the method including the steps of:-

- providing a substrate and a MEMS layer, the MEMS layer arranged on one side of the substrate;

- applying a further layer arranged to protect the MEMS layer to said one side of the substrate;

- separating the substrate into discrete parts by performing at least one operation including a back etching operation from a side of the substrate opposed to the side having the MEMS layer, each discrete part carrying at least one MEMS part of the MEMS layer;

- subsequent to the step of separating the substrate into discrete parts, applying a holding means to said opposed side of the substrate;

- defining individual chips by performing at least one operation, including an etching operation on the further layer, each of said chips being composed of one of said discrete parts of the substrate, at least one part of the MEMS layer and a part of the further layer; and

causing the individual chips to be released from the holding means for removal from the holding means.

Preferably the step of defining individual chips is performed after the step of applying a holding means to the substrate.

The method may further include the step of bonding the holding means to the substrate.

In a preferred embodiment the holding means is bonded to the substrate by means of an adhesive which is curable by exposure to ultraviolet (UV) light and in which the method further includes the step of exposing localized regions of the holding means to UV light to release one chip at a time from the holding means to enable each chip to be removed individually from the holding means.

Preferably the method further includes the step of applying a handling means to the holding means, the handling means being transparent to UV light so that UV light is transmitted through the handling means to cure the adhesive of the holding means.

It is advantageous if the method includes the step of removing each chip from the holding means by a transporting means.

The step of removing each chip from the holding means may include reciprocating each chip individually over a source of UV light.

The holding means may be bonded to the layer by means of an adhesive which is curable by exposure to ultraviolet (UV) light. By "curable" is meant that the adhesive loses its adhesive properties when exposed to UV light. Thus, the method may include exposing localised regions of the holding means to UV light to release one chip at a time from the holding means to enable each chip to be removed individually from the holding means. It will be appreciated that the handling means is transparent to UV light so that UV light is transmitted through the handling means to cure the adhesive of the holding means.

The handling means may be in the form of a glass, quartz, alumina or equivalent wafer.

The method may finally include removing each chip from the holding means by a transporting means.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is now described by way of example with reference to the accompanying diagrammatic drawings in which:-

Figures 1 to 8 show various stages in a method of fabricating MEMS devices, in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

In an initial step, illustrated at 10 in Figure 1 of the drawings, of a method of fabricating a MEMS device, in accordance with the invention, a layer 10 is provided to be applied to a first surface 12 of a silicon substrate or wafer 14.

The wafer 14 carries a surface macromachined MEMS layer 16 on the first surface 12 of the wafer 14. The MEMS layer 16 comprises individual MEMS elements 18.

The invention has particular application in the manufacture of ink jet printheads. For ease of explanation, the invention will be described with reference to that application. Thus, the layer 10 is a nozzle guard layer or wafer which is applied to the surface 12 of the silicon substrate 14. Each individual MEMS element 18 is in the form of a nozzle assembly. Each nozzle assembly 18 comprises an ink ejection nozzle and its associated actuator. The actuator acts on the nozzle for effecting ink ejection, on demand.

The purpose of the method of manufacture is to form individual MEMS chips 20 (Figure 8).

Hence, after the nozzle guard layer 10 has been applied to the wafer 14, the wafer 14 is turned over to expose a reverse side 22 as shown in Figure 3 of the drawings.

Various operations are then carried out on the wafer 14. In particular, the wafer 14 is back etched, from the surface 22 towards the surface 12 to separate the silicon wafer into discrete parts 24. In addition, in this application of the invention, ink inlet apertures 26 are etched through the parts 24. It is to be noted that each part 24 comprises a plurality of MEMS elements 18 and a bond pad 28. Also, as shown more clearly in Figure 1 of the drawings, the layer 10 has a plurality of struts 30 which support a body 32 of the layer 10 in spaced relationship above the surface 12 of the wafer 14 such that the MEMS elements 18 and the bond pads 28 are protected by the body 32. The struts 30 define chambers 34 and 36. The chambers 34 overlie the bond pads 28 while the chambers 36 overlie the array of MEMS elements 18 of each part 24.

A holding means in the form of an adhesive tape 38 is bonded to the surface 22 of the layer 14 as illustrated in Figure 5 of the drawings. The tape 38 is bonded to the layer 14 by means of a curable adhesive. The adhesive is curable in the sense that it loses its adhesive properties or "tackiness" when exposed to ultraviolet (UV) light.

Depending on the equipment used, a handling means in the form of a glass, quartz, alumina or other transparent handle wafer 40 is secured to an opposite surface of the tape 38.

The wafer 40, the tape 38, the silicon wafer 14 and the nozzle guard layer 10 define a laminate 42. The laminate 42 is then turned over, as shown in Figure 7 of the drawings.

Predetermined operations are carried out on the layer 10. More particularly, passages 44 are etched through the layer 10 from an outer surface 46 towards the chambers 36. In addition, individual nozzle guards 48 are formed by etching to remove material as shown at 50 in Figure 7 of the drawings.

The removal of this material exposes the bond pads 28 of each chip 20. Upon completion of this operation, the individual chips 20 are formed.

In this embodiment of the invention, each chip 20 has a plurality of MEMS elements 18 in an array formed thereon.

The laminate 42 is placed on an xy wafer stage (not shown) which is reciprocated, as illustrated by arrow 52 in Figure 8 of the drawings. Each MEMS chip 20, when it is desired to remove it, is exposed to UV light as indicated by arrows 54 through a mask 56. This cures the adhesive of the tape 40 locally in a region beneath one particular MEMS chip 20 at a time to enable that MEMS chip 20 to be removed from the tape 38. The MEMS chip 20 is removed from the tape 38 by means of a transporting means including a vacuum pickup 58.

Hence, it is an advantage of the invention, that a method of fabrication is provided which facilitates the performing of various operations to fabricate the individual MEMS chip 20 and which facilitates removal of the MEMS chips 20 for packaging. It will be appreciated that devices of the kind in question are measured in micron dimensions. Accordingly, the MEMS elements 18 on such devices are extremely fragile. The provision of the nozzle guard layer 10 and the use of the UV curable tape 38 facilitates that the MEMS elements 18 are not touched by solids or liquids after they are released by the release etch.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

CLAIMS

1. A method of fabricating MEMS devices, the method including the steps of:
applying a protective structure to a front surface of a substrate on which a plurality of spaced MEMS structures is positioned, the protective structure having a body and a plurality of posts extending from the body, the protective structure being applied so that a strut is received between adjacent MEMS structures;
separating the substrate such that each MEMS structure is positioned on a respective discrete substrate;
applying a holding means to a back surface of the substrate;
separating the body such that the protective structure is divided into discrete protective structures, with a MEMS structure being received between pairs of consecutive posts; and
releasing the back surface from the holding means.
2. A method as claimed in claim 1, in which the step of separating the substrate includes the step of etching the substrate from a back surface to the front surface.
3. A method as claimed in claim 1, in which the step of applying a holding means to the back surface of the substrate includes the step of applying an adhesive tape to the back surface.
4. A method as claimed in claim 3, which includes the step of applying a handling means to the adhesive tape.
5. A method as claimed in claim 3, in which the adhesive tape is released from the back surface by irradiating the adhesive tape with ultra-violet light.
6. A method as claimed in claim 1, which includes the step of etching fluid passages through the substrate, from the back surface, so that each MEMS structure is in fluid communication with a respective fluid passage.