Title: EQUIPMENT FOR REMOVING PROTECTIVE COATINGS FROM SUBSTRATES

Abstract: Apparatuses and systems that enable selective removal of protective coatings from substrates are disclosed. Such a material removal system may use pressurized solid carbon dioxide (CO₂) (i.e., dry ice) to remove a selected portion of a protective coating from a substrate. The material removal system may include one or more templates that provide selectivity in removing protective coatings from one or more substrates, fixtures for holding one or more substrates in place while material removal processes occur and apparatuses for positioning one or more substrates at desired locations in material removal systems.
EQUIPMENT FOR REMOVING PROTECTIVE COATINGS FROM SUBSTRATES

CROSS-REFERENCE TO RELATED APPLICATIONS

Claims to the benefit of the August 29, 2014, filing date of U.S. Provisional Patent Application 62/044,013, titled MULTI-AXIS PLATFORM FOR USE WITH A MATERIAL REMOVAL APPARATUS ("the '013 Provisional Application"), and the August 29, 2014, filing date of U.S. Provisional Patent Application 62/044,097, titled HOLD-DOWN FIXTURE FOR USE IN REMOVING A PROTECTIVE COATING FROM SELECTED AREAS OF A SUBSTRATE ("the '097 Provisional Application"), are hereby made. The entire disclosures of the '013 Provisional Application and the '097 Provisional Application are hereby incorporated by reference.

TECHNICAL FIELD

This disclosure relates generally to apparatuses and systems that enable selective removal of protective coatings from substrates. In some embodiments, the material removal apparatuses or systems may comprise dry ice blasting systems, which are direct pressurized solid carbon dioxide (CO2) (i.e., dry ice) toward a protective coating on a substrate. More specifically, this disclosure relates to apparatuses that are configured to facilitate the removal of selected portions of protective coatings from one or more substrates, including dry ice blasting systems, templates that provide selectivity in removing protective coatings from one or more substrates, fixtures for holding one or more substrates in place while material removal processes occur and apparatuses for positioning one or more substrates at desired locations in material removal systems.

SUMMARY

Material removal apparatuses and systems may be used to remove portions of a material from a substrate. Some material removal apparatuses and systems may be configured to selectively remove material from substrates. In a particular implementation, material removal apparatuses and systems may be used to selectively remove portions of protective coatings (e.g., moisture-resistant coatings, such as parylene coatings) from substrates, including, but not limited to, subassemblies and assemblies of electronic devices (e.g., portable electronic devices, wearable electronic devices and other wearable devices, electronic devices that are expected to be exposed to the elements and medical devices).
devices). So-called "dry ice blasting" processes, equipment and systems have been found to be particularly effective for selectively removing protective coatings from substrates.

Dry ice blasting may be used to remove a protective coating without leaving any chemical residue, as dry ice sublimes (i.e., vaporizes from a solid to a gas) at room temperature, and without generating any secondary waste material. Dry ice blasting systems accelerate particles or pellets of dry ice with pressurized air or a pressurized gas. A dry ice blasting system may pressurize the dry ice and direct it toward a substrate as a stream or jet or as a curtain or sheet. The location of the stream or jet or the curtain or sheet may remain stationary as the dry ice blasting equipment operates. In embodiments where the impact area of the dry ice will not simultaneously cover all of the areas of a substrate from which one or more portions of a protective coating is to be removed, a nozzle from which the dry ice is ejected and/or the substrate may be moved laterally (i.e., along and x-axis and a y-axis) to enable the dry ice to contact all of the areas of a protective coating that are to be removed. In some embodiments, it may also be desirable to select the spacing between the nozzle and the substrate (i.e., along a z-axis).

In one aspect, this disclosure relates to dry ice blasting systems with chambers that are configured to receive one or more substrates and within which dry ice, under pressure, may be directed toward the substrate(s).

In another aspect, platforms are disclosed that are configured to be placed in and, optionally, removed from the chambers of dry ice blasting systems and to move one or more substrates relative to pressurized dry ice. Such a platform may include a support and an actuator. The support may be configured to receive and, optionally, engage one or more substrates, and to hold each substrate supported thereby in place as pressurized dry ice is directed onto that substrate. The actuator may be configured to move the support along at least one axis relative to (e.g., under) the pressurized dry ice. In some embodiments, the actuator may be configured to move the support and any substrates carried thereby along two or more axes, such as the x-axis and the y-axis of a chamber of dry ice blasting equipment. The actuator may also be configured to move the support and any substrates carried thereby along a z-axis (i.e., toward and away from a head from which the pressurized dry ice is expelled).

As an alternative to the use of a movable platform in a chamber of a dry ice blasting system, the nozzle(s) of the dry ice blasting system, from which dry ice is ejected, may be configured to move in multiple axes (e.g., x-axis, y-axis and/or z-axis) relative to a fixed location, or platen of the dry ice blasting system, which platen is
configured to hold one or more substrates from which a protective coating may be removed.

In some embodiments, a movable nozzle and a movable platform may be used in conjunction with one another to hold and selectively remove protective coatings from one or more substrates. Both the nozzle and the platform may move in one or more common directions (e.g., x-axis, y-axis and/or z-axis) or the nozzle may move in some directions (e.g., z-axis) while the platform moves in different directions (e.g., x-axis and y-axis).

In another aspect, this disclosure relates to templates that may be used to facilitate the removal of portions of a protective coating from selected locations of a substrate. Such a template may be configured for assembly with at least one surface or side of a substrate, such as an electronic device (e.g., an electronic component, an electronic subassembly or an electronic assembly). The template may seal against the surface against which it is assembled, and each portion of the protective coating that is to be removed from the substrate may be exposed through a corresponding aperture of the template.

Fixtures for holding one or more substrates in place during dry ice blasting or other material removal processes are also disclosed. Such a fixture may be configured to receive one or more substrates and to position the one or more substrates in desired orientations. The fixture and the substrate(s) may then be received by a platen or a support plate of a material removal system and, along with the platen or the support plate, position each substrate in a desired orientation relative to a material removal component of the material removal system (e.g., a nozzle of a dry ice blasting system). As an alternative to directly receiving a substrate, each receptacle of a fixture may be configured to receive one or more templates that have been assembled with a substrate.

Another aspect of this disclosure relates to methods for removing protective coatings or other materials from substrates using any combination of apparatuses of this disclosure. Such a method may include assembling at least one template with at least one substrate, placing each substrate on a platen or a support plate, securing each substrate in place on the platen or the support plate, adjusting positions of a nozzle of a dry ice blasting system and each substrate relative to one another and/or directing pressurized dry ice toward each substrate. The template and/or selective movement of the platen/support plate and/or the nozzle may sequentially expose a plurality of different areas of a protective coating on a substrate to the pressurized dry ice and enable the pressurized dry ice to remove selected portions of the protective coating from each substrate.
Other aspects, as well as features and advantages, of the disclosed subject matter
will be apparent to those of ordinary skill in the art through consideration of the ensuing
description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 illustrates an embodiment of a dry ice blasting system;

FIG. 2 depicts an embodiment of a movable platform that may be used with
various embodiments of dry ice blasting systems, including, but not limited to, the
embodiment depicted by FIG. 1;

FIG. 3 provides an exploded view of the embodiment of movable platform shown
in FIG. 2;

FIGS. 4A-4C show an embodiment of a template that may be used to hold an
embodiment of a substrate and to expose selected regions on at least one side of the
substrate to dry ice blasting processes, such as those effected by way of an embodiment of
a dry ice blasting system according to this disclosure;

FIGS. 5A and 5B show an embodiment of a substrate from which selected portions
of a protective coating have been removed using a dry ice blasting process and the
embodiment of template shown in FIGS. 4A-4C; and

FIG. 6 provides an assembly view another embodiment of a fixture that may be
used in dry ice blasting processes, including those carried out by various embodiments of
dry ice blasting systems, the embodiment of fixture depicted by FIG. 5 being configured
to receive and organize a plurality of templates.

DETAILED DESCRIPTION

FIG. 1 illustrates an embodiment of a dry ice blasting system 1. The dry ice
blasting system 1 may be used to selectively remove portions of a protective coating
(e.g., a parylene coating or a coating that includes multiple layers formed by atomic layer
deposition (ALD) processes) from a substrate (e.g., an electronic device assembly). When
dry ice blasting processes are used, removal of selected portions of a protective coating
may occur with no chemical residue, as dry ice sublimes to gaseous carbon dioxide
(CO₂) at room temperature, and without generating any secondary waste material other
than the material that has been removed from the substrate, as dry ice and CO₂ are
generally considered to be non-toxic.
In the depicted embodiment, the dry ice blasting system 1 includes dry ice supply 2, a pressurization component 3, a chamber 4, a nozzle 5 and a platen 7. The pressurization component 3 is associated with the dry ice supply 2 in a manner that retrieves dry ice from the dry ice supply 2 and conveys the dry ice under pressure to the nozzle 5, which is located within the chamber 4. At the nozzle 5, the pressurized dry ice is directed toward the platen 7 and any substrates 60 that are carried by the platen 7.

The dry ice supply 2 may store dry ice in any suitable form, for example, as a block, as pellets or as particles. The pressurization component 3, which may be part of the dry ice supply 2 or associated with the dry ice supply 2, may employ pressurized air or a pressurized gas to accelerate the particles or pellets of dry ice. The pressurization component 3 may be configured to operate for a sufficient duration of time to remove a desired amount of protective material of the protective coating from a substrate (e.g., partially remove the protective material to thin the protective coating at one or more selected regions and/or completely remove the protective material from one or more selected regions of the protective coating).

The nozzle 5 of the dry ice blasting system 1 may be configured to direct the dry ice toward the platen 7 or toward a substrate carried by the platen 7, and to define the shape of an area the dry ice impacts on the platen 7 or on a substrate (not shown) carried by the platen 7. In some embodiments, the nozzle 5 may be configured to emit a narrow stream, or jet, of dry ice (e.g., a stream having a width of about 3 mm or less, a stream having a width of about 2 mm or less, a stream having a width of about 1 mm or less or a stream having a width of about 0.5 mm less). The stream may have any desired cross-sectional shape and, thus, impact an area having any desired shape (e.g., circular, oval, rectangular, square or triangular). In other embodiments, the nozzle 5 may be configured to eject a curtain or sheet of dry ice. In a specific embodiment, the fan nozzle 5 may comprise a fan nozzle with a 1.6 mm x 20 mm opening. Such a curtain or sheet of dry ice may have any desired width (e.g., about 2 mm wide or less, about 1.5 mm wide or less, about 1 mm wide or less or about 0.5 mm wide or less) and any desired length (e.g., about 5 mm, about 1 cm, about 2 cm, about 5 cm or about 10 cm).

The dry ice blasting system 1 may include a gantry 6 that carries the nozzle 5 and determines a lateral (i.e., x-axis, y-axis, or X-Y) and/or vertical (i.e., z-axis, or Z) position of the nozzle 5 within the chamber 4 and over the platen 7. Any suitable configuration of gantry 6 may be employed in the dry ice blasting system 1.
Optionally, the dry ice blasting system 1 may include an exhaust system 8. The exhaust system 8 may be associated with an interior of the chamber 4 in a manner that enables carbon dioxide (C\textsubscript{2}O\textsubscript{2}) to be drawn from the interior of the chamber 4 and conveyed to another location (e.g., to the atmosphere or to a storage/waste container).

The platen 7 may include positioning elements that ensure that a particular substrate (e.g., a subassembly of an electronic device) is positioned in a desired orientation and/or that secure the substrate in the desired orientation. As an alternative to including such positioning elements, the platen 7 may be configured to receive separate positioning elements.

The platen 7 of a dry ice blasting system 1 may be configured to be move in a variety of directions within the interior of the chamber 4. Without limitation, the platen 7 may be configured to be raised and lowered (i.e., to move along a z-axis). The platen 7 may be configured to move laterally, for example, from side to side (i.e., along an x-axis) and/or from front to back (i.e., along a y-axis). Alternatively, a position of the platen 7 within the chamber 4 of a dry ice blasting system 1 may be fixed.

A platen 7 of a dry ice blasting system 1 may be configured to receive a moveable platform 10, such as that depicted by FIG. 2 (in assembled form) and FIG. 3 (in exploded form). The moveable platform 10 may be secured to the platen 7 in any suitable manner (e.g., with features that mutually engage features of the platen 7, with intermediate engagement features that are configured to be assembled between the platen 7 and the moveable platform 10 or by way of an interference fit between corresponding features of the platen 7 and the moveable platform 10). A moveable platform 10 may be configured to enable movement of one or more substrates laterally (i.e., side-to-side, or along an x-axis, and front-to-back, or along a y-axis). A movable platform 10 may also be configured to move one or more substrates vertically (i.e., up and down, or along a z-axis).

The embodiment of movable platform 10 depicted by FIGs. 2 and 3 includes a base plate 12, a z-movement system 20, an x-movement system 30, a y-movement system 40 and a support plate 46. Such a moveable platform 10 may enable movement of a substrate within a dry ice blasting system 1 (FIG. 1) (e.g., a manually operable dry ice blasting system 1 or an automated dry ice blasting system 1) or within any other embodiment of material removal system to enable removal of a material, such as a protective coating, from selected locations of the substrate.
The base plate 12 of the movable platform 10 may be configured for placement on
the platen 7 (FIG. 1) of a dry ice blasting system 1 (FIG. 1). The base plate 12 and the
platen 7 may include complementarily configured features, which may ensure that the
base plate 12 is properly positioned, or aligned, on the platen 7 and/or that the base
plate 12 is secured to the platen 7. In some embodiments, these complementarily
configured features may be carried by and/or formed in surfaces of the base plate 12 and
the platen 7 that are configured to oppose, or face, one another.

The base plate 12 may include one or more handles 14, with two handles 14 being
shown in the embodiment of dry ice blasting system 1 depicted by FIGs. 2 and 3). The
handles 14 may facilitate placement of the movable platform 10 within the chamber 4
(FIG. 1) of a dry ice blasting system 1 (FIG. 1) and on the platen 7 (FIG. 1) of the dry ice
blasting system 1, as well as removal of the movable platform 10 from the platen 7 and
the chamber 4.

In embodiments where the movable platform 10 includes a z-movement
system 20, the z-movement system 20 may be secured to the base plate 12 of the movable
platform 10. While the z-movement system 20 may have any of a variety of suitable
configurations, FIGs. 2 and 3 depict an embodiment in which the z-axis system 20
includes a stand 22 and a support plate 26. The stand 22 includes at least one actuator 24
(e.g., a manually operable dial or one or more suitable motors and associated controls)
that is configured to raise and lower the support plate 26.

In embodiments where the movable platform 10 includes an x-movement
system 30, the x-movement system 30 may be secured to the support plate 26 of a
z-movement system 20 or, if the movable platform 10 does not include a z-movement
system 20, to the base plate 12 of the moveable platform 10. An x-movement system 30
may include one or more elements that facilitate side-to-side movement, such as the
rails 32 and sliders 34 depicted by FIGs. 2 and 3. Each rail 32 may be oriented to extend
from a location on one side of the base plate 12 and, thus, of the movable platform 10 to a
location on an opposite side of the base plate 12 and the moveable platform 10. Each
slider 34 may be configured to engage a rail 32 and to move along a length of the rail 32,
in some embodiments with little or no friction. The sliders 34 may be secured to a bottom
surface of a support plate 36 of the x-movement system 30 to enable the support plate 36
to move along the lengths of the rails 32 and, thus, from side-to-side relative to the base
plate 12 and the remainder of the movable platform 10.
In embodiments where the movable platform 10 includes a y-movement system 40, as illustrated, the y-movement system 40 may be secured to the support plate 36 of an x-movement system 30. If the movable platform 10 lacks an x-movement system 30 but includes a z-movement system 20, the y-movement system 40 may be secured to the support plate 26 of the z-movement system 20. If the movable platform 10 lacks both an x-movement system 30 and a z-movement system 20, the y-movement system 40 may be secured to the base plate 12 of the movable platform 10. In any of these embodiments, the y-movement system 40 may include one or more elements that facilitate front-to-back movement, such as the rails 42 and sliders 44 depicted by FIGs. 2 and 3. Each rail 42 may be oriented to extend from a location at or near a front the base plate 12 and, thus, of the movable platform 10 to a location at or near a rear of the base plate 12 and the moveable platform 10. Each slider 44 may be configured to engage a rail 42 and to move along a length of the rail 42, in some embodiments with little or no friction. The sliders 44 may be secured to a bottom surface of a support plate 46 of the y-movement system 40 to enable the support plate 46 to move along the lengths of the rails 42 and, thus, from front-to-back relative to the base plate 12 and the remainder of the movable platform 10.

The uppermost support plate 26, 36, 46 of the movable platform 10 may be configured to receive one or more substrates (not shown) that are to be processed by a dry ice blasting system 1 (FIG. 1). In the depicted embodiment, support plate 46 is the uppermost support plate. In some embodiments, the uppermost support plate 46 may include or be configured to receive one or more elements that position each substrate in a desired orientation and/or secure each substrate to an upper surface of the support plate 46.

As illustrated by FIGs. 2 and 3, in some embodiments, a movable platform 10 may include one or more actuation elements 50. Each actuation element 50 may be configured to cause the uppermost support plate (i.e., support plate 46 in the depicted embodiment) to move in one or more desired directions. In the illustrated embodiment, each actuation element 50 may comprise a handle, which may be manually grasped to enable manipulation of the lateral (i.e., x-axis and/or y-axis) positions of the support plate 46 and any substrates carried by the support plate 46. In other embodiments, the actuation element 50 may enable automated movement of the support plate 46 (e.g., by way of one or more motors and controls associated with the motor(s)).
In addition to showing the primary elements of an embodiment of a movable platform, FIG. 3 shows a specific, but non-limiting, embodiment in which those elements may be secured to one another. Specifically, FIG. 3 illustrates the use of screws to secure the various elements to one another in intended arrangements. Other options for securing various elements of a moveable platform 10 to one another include the use of rivets, welds, brazing, adhesive materials, press fits, interferences fits and the like.

In addition to enabling movement of one or more substrates (not shown) within the chamber 4 (FIG. 1) of a dry ice blasting system 1 (FIG. 1), the movable platform 10 may simplify the process of arranging the one or more substrates over the platen 7 of a dry ice blasting system 1. Since the movable platform 10 is configured to be removed from the chamber 4 (FIG. 1) of the dry ice blasting system 1, one or more substrates may be placed on an uppermost support plate 46 of the movable platform 10 without the impediments that would otherwise be presented by various features defining the chamber 4 of the dry ice blasting system 1. With each substrate in place upon the uppermost support plate 46, the movable platform 10 may then be placed into the chamber 4, and the substrate(s) may then be subjected to dry ice blasting.

As an alternative to placing one or more substrates directly on the platen 7 (FIG. 1) of a dry ice blasting system 1 (FIG. 1) or directly on the uppermost support plate 46, of a movable platform 10 (FIGs. 2 and 3) that is configured to be introduced into the chamber 4 (FIG. 1) of a dry ice blasting system 1 and onto the platen 7 of the dry ice blasting system 1, the one or more substrates 60 may be secured to a template 100, as illustrated by FIGs. 4A-4C. The template 100 may then be secured to the platen 7 or the uppermost support plate 46.

FIGs. 4A-4C illustrate an embodiment of a template 100 that has been assembled with a substrate 60. The substrate 60 may comprise a subassembly of an electronic device or an assembly of an electronic device, both of which may be referred to herein as an "electronic device assembly." In the illustrated embodiment, the substrate 60 comprises a printed circuit board (PCB), although a template 100 according to this disclosure may be configured to receive any of a variety of different types of electronic devices (e.g., electronic device assemblies that include flexible circuit boards (FCBs), frames or housing elements), as well as a variety of other types of substrates 60.

The material(s) from which the elements 102 and 106 of a template 100 are made may withstand material removal processes without suffering from undesired degradation. Without limitation, the elements 102 and 106 may be made from a suitable metal.
(e.g., aluminum, stainless steel or steel), a resin or a rigid thermoplastic material. While the elements 102 and 106 may have any suitable configuration, as shown in FIGs. 4A-4C, they may be generally flat.

When the elements 102 and 106 of such an embodiment of template 100 are assembled with a substrate and the elements 102 and 106 are assembled with each other, the substrate 60 may be sandwiched and held in place between the elements 102 and 106. The elements 102 and 106 may be secured to each other in any suitable manner. Without limitation, corresponding features of the elements 102 and 106 may engage each other in an interference fit or a snap-fit as the elements 102 and 106 are properly assembled with each other.

While the template 100 shown in FIGs. 4A-4C includes two elements 102 and 106—a top element and a bottom element, templates that only include one element (e.g., a top element or a bottom element) are also within the scope of this disclosure. As shown by FIG. 4A, a first element 102 of the template 100 is configured for assembly over a first side 64 of a substrate 60 and a second element 106 of the template 100 is configured to be assembled over a second side 66 of the substrate 60. Inner surfaces 105 and 109 of the elements 102 and 106 of the template 100 are respectively configured to be placed against the first side 64 and the second side 66 of the substrate 60.

FIGs. 4B and 4C respectively show views of the outer surfaces 103 and 107 of the elements 102 and 106, to which apertures 104 and 108 open. The apertures 104 and 108 are configured to be positioned over parts of a protective coating that are to be removed from the substrate 60. Thus, as dry ice is directed into one or more of the apertures 104, 108, protective material may be removed from portions of the protective coating that are exposed through each aperture 104, 108. Accordingly, a template 100 that includes elements 102 and 106 with apertures 104 and 108, respectively, that are configured to be positioned over opposite sides 64 and 66 of a substrate 60 may be configured to be positioned in an upright orientation and an inverted orientation to enable the selective removal of portions of a protective coating from each side 64, 66 of the substrate 60.

In some embodiments, the inner surfaces 105 and 109 of the elements 102 and 106 of the template 100 may be at least partially lined with a material that will seal against the sides 64 and 66 of the substrate 60. A seal may also protect the substrate 60 from damage that might otherwise be cause by vibration of the template 100 and/or the substrate 60 as material is removed from the substrate 60. In more specific embodiments,
the seal(s) on the inner surface 105, 109 of an element 102, 106 of the template 100 may comprise a foam material (e.g., polystyrene foam or polyurethane foam) carried by the inner surface 105, 109. The seal(s) may prevent movement of each substrate 60 relative to an element 102, 106 of the template 100, prevent dry ice from reaching one or more locations on a side 64, 66 of the substrate 60 on which a protective coating is to remain and/or prevent damage to the substrate 60 or to regions of a protective coating that are to remain intact on the substrate 60.

In FIGs. 5A and 5B, the substrate 60 is shown after a portion of a protective coating 74, 76 has been removed from each side 64, 66 of the substrate 60. More specifically, FIGs. 5A and 5B show that features and/or components 75a, 75b, etc.; 77a, 77b, etc., of the substrate 60 have been exposed through the protective coating 74, 76 on each side of the substrate 60. As indicated previously herein, the depicted embodiment of substrate 60 comprises a flexible circuit board. As shown in FIG. 5A, on side 64, portions of a protective coating 74 that were located over a ground trace 75a, a board-to-board connector 75b (e.g., a plug-in type connector or a zero insertion force (ZIF) connector) and a wireless connector 75c (e.g., a radiofrequency connector or a BLUETOOTH® connector) have been removed to expose these features and/or components. In FIG. 5B, which shows side 66 of the substrate 60, a two board-to-board connectors 77a and 77b and a wireless connector 77c have been exposed through protective coating 76.

Turning now to FIG. 6, an embodiment of a fixture 120 is depicted. Fixture 120 provides a plurality of receptacles 130a, 130b, etc., for receiving a plurality of substrates 60 and, optionally, for receiving a plurality of substrate 60-template 100 assemblies (see, e.g., FIGs. 4A-C). In some embodiments, the fixture 120 includes a pair of elements 122 and 126 that, together, define the plurality of receptacles 130a, 130b, etc., each of which is configured to receive a substrate 60 and/or a substrate 60-template 100 assembly.

The elements 122 and 126 of a fixture 120 may be made from any suitable metal. Without limitation, metal (e.g., aluminum, stainless steel or steel), a resin and/or a rigid thermoplastic material may be used to form the elements 122 and 126 of the fixture 120.

In some embodiments, such as those depicted by FIG. 6, each receptacle 130a, 130b may be associated with a one or more exposure apertures 124a and 128a, 124b and 128b, etc., with dimensions that may expose a majority of a corresponding side of a substrate 60 assembled with that receptacle 130a, 130b. Such an embodiment of fixture 120 may be configured for use with separate templates 100.
(FIGs. 4A-4C) that, in turn, are configured to be positioned adjacent to at least one side 64, 66 of a substrate 60. More specifically, each receptacle 130a, 130b of the fixture 120 may be configured to receive a template 100. Even more specifically, each receptacle 130a, 130b of the fixture 120 may be configured to receive any of a variety of templates 100 with standardized outer dimensions. Such a configuration may enable different templates 100 that are configured for use with different substrates 60 (including, but not limited to, substrates 60 with different shapes and/or dimensions) to be used with a single fixture 120. Such a configuration may also enable templates 100 with different arrangements of apertures 104, 108 (FIGs. 4A-4C) to be used with the same fixture 120.

When the elements 122 and 126 of a fixture 120 are assembled with one another, they may be secured to each other in any suitable manner. Without limitation, corresponding features of the elements 122 and 126 may engage each other (e.g., in an interference fit or a snap fit). Alternatively, the elements 122 and 126 may be secured to one another with suitable coupling elements, such as clamps, bolts (and, optionally, nuts) and the like.

In embodiments where a fixture 120 is configured to hold substrates 60 that have been assembled with complementary templates 100 (FIGs. 4A-4C), as the elements 122 and 126 of the fixture 120 are assembled with one another and secured in the assembled relationship, seals on the inner surfaces 105 and 109 (FIGs. 4A-4C) of the elements 102 and 106 (FIGs. 4A-4C) of the template 100 may be forced against adjacent sides 64 and 66 (FIG. 4A), respectively, of the substrate 60, forming a tight seal against the sides 64 and 66 of the substrate 60.

Although the preceding disclosure provides many specifics, these should not be construed as limiting the scope of any of the ensuing claims. Other embodiments may be devised which do not depart from the scopes of the claims. Features from different embodiments may be employed in combination. The scope of each claim is, therefore, indicated and limited only by its plain language and the full scope of available legal equivalents to its elements.
 CLAIMS

What is claimed:

1. A movable platform for use with a material removal apparatus, comprising:
   a support configured to receive at least one substrate and to hold the at least one substrate
   in place under application of pressurized dry ice; and
   an actuator configured to move the support along at least one axis relative to the
   pressurized dry ice.

2. The platform of claim 1, wherein the actuator is configured to move the support along at least two axes relative to a direction of application of the pressurized dry ice.

3. The platform of claim 2, wherein the actuator is configured to move the support along an x-axis and along a y-axis.

4. The platform of claim 3, wherein the actuator is further configured to move the support along a z-axis, toward or away from an outlet of the pressurized dry ice.

5. Dry ice blasting equipment, comprising:
   a chamber for receiving at least one substrate;
   a nozzle within the chamber for directing pressurized dry ice toward the at least one
   substrate;
   a movable platform within the chamber configured to support the at least one substrate
   relative to the nozzle and to position the at least one substrate relative to the
   nozzle, the movable platform being configured to move the at least one substrate
   along a plurality of axes.

6. The dry ice blasting equipment of claim 5, wherein the nozzle is configured to direct the pressurized dry ice as a stream or as a curtain.
7. The dry ice blasting equipment of claim 5 or claim 6, wherein the nozzle is configured to move along at least one axis.

8. The dry ice blasting equipment of claim 7, wherein the at least one axis the nozzle is configured to move along is different from the plurality of axes along which the movable platform is configured to move the at least one substrate.

9. The dry ice blasting equipment of claim 7, wherein the at least one axis the nozzle is configured to move along is the same as an axis along which the movable platform is configured to move the at least one substrate.

10. A method for removing material from a substrate, comprising: placing at least one substrate on a platen or a support plate; directing pressurized dry ice toward the at least one substrate; and selectively moving at least one of the platen or the support plate and a nozzle from which the pressurized dry ice is ejected to sequentially expose a plurality of different areas of a protective coating on the at least one substrate to the pressurized dry ice and to enable the pressurized dry ice to remove the plurality of different areas of the protective coating from the at least one substrate.

11. The method of claim 10, wherein placing at least one substrate on the platen or the support plate comprises placing an electronic assembly or an electronic subassembly on the platen or the support plate.

12. A template for use with a material removal apparatus, comprising: a first element configured to be positioned against over a first side of a substrate, the top element including at least one exposure aperture for exposing at least a portion of the substrate; and a second element configured to be positioned against a second side of the substrate, the first element and the second element configured to be secured to one another in a manner that secures the substrate in place and exposes at least the portion of the substrate through the at least one exposure aperture.
13. The template of claim 12, wherein the second element also includes at least one exposure aperture, the at least one exposure aperture of the second element configured to expose at least a portion of the second side of the substrate.

14. The template of claim 12, wherein the first element includes a plurality of exposure apertures.

15. The template of claim 12, wherein the first element is configured to limit exposure of at least a portion of the substrate from which material is not to be removed.

16. The template of any of claims 12-15, wherein at least one of the first element and the second element includes a seal configured to seal against the substrate.

17. The template of claim 16, wherein the seal comprises foam.

18. The template of any of claims 12-15, wherein at least one of the first element and the second element is configured to be received by and secured in place relative to a platen or a support plate of a material removal apparatus.

19. The template of claim 18, wherein at least one of the first element and the second element is configured to be received by and secured in place relative to a platen or a support plate of a dry ice blasting system.

20. The template of any of claims 12-15, wherein the first element and the second element are configured to be received by another, larger fixture that is configured to secure the substrate in place relative to a platen or a support plate of a material removal apparatus.

21. The template of claim 20, wherein the first element and the second element are configured to be received by another, larger fixture that is configured to receive a plurality of assemblies of substrates and templates and to secure the plurality of assemblies in place relative to the plate or the support plate of the material removal apparatus.
22. A material removal assembly, comprising:
at least one substrate;
at least one template configured to be assembled with the at least one substrate to limit
exposure of the at least one substrate or a protective coating on the at least one
substrate to at least one selected region; and
a fixture defining a receptacle for the template, the fixture being configured to position
and/or secure the at least one substrate to a platen or a support plate of a material
removal system.

23. The material removal assembly of claim 22, wherein the a fixture
comprises a first element and a second element defining the receptacle for the template,
the first element configured to be positioned over a first side of the template, the second
element configured to be positioned over a second side of the template.

24. The material removal assembly of claim 22, wherein the substrate
comprises an electronic subassembly or an electronic assembly.

25. The material removal assembly of any of claims 22-24, wherein the at
least one substrate includes the protective coating, at least a portion of which is to be
removed through at least one aperture of the template.

26. A method for removing material from a substrate, comprising:
assembling a substrate with a template;
positioning the template relative to a platen or a support plate of a material removal
system; and
removing a material from the substrate through at least one aperture of the template using
the material removal system.

27. The method of claim 26, wherein assembling further comprises:
assembling the template with a fixture, wherein positioning the template relative to the
platen or the support plate of the material removal system comprises positioning
the fixture relative to the platen or the support plate of the material removal
system.
28. The method of claim 26 or claim 27, wherein removing the material from the substrate comprises removing a portion of a protective coating from the substrate.

29. The method of claim 26 or claim 27, wherein removing the material from the substrate comprises directing dry ice under pressure into the at least one aperture of the template.
### Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

- "-Continued Within the Next Supplemental Box:"**-

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-4

### Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.
### INTERNATIONAL SEARCH REPORT

**INTERNATIONAL APPLICATION**

**International application No.**

PCT/US 15/47832

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC (8) -**
B24C 1/04, 3/12; H01L 21/64, 21/67 (2015.01)

**CPC -**
B24C 1/003, 1/04, 1/086; H01L 21/64, 21/67

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC(8): B24C 1/04, 3/12; H01L 21/64, 21/67 (2015.01)

CPC: B24C 1/003, 1/04, 1/086; H01L 21/64, 21/67

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, Other Countries (INPADOC), RU, AT, CH, TH, BR, PH), ProQuest, Google/Google Scholar Protective, Parylene, ALD, atomic w layer, Coating, layer, Substrate, Plate, platform, Dry_ice, Carbon dioxide, Nozzle, Spray*, applicat *, Multi_axis, Multi_axes, x_axis, y_axis, z_axis

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>EP 1 317 995 A1 (SIEMENS AKTIENGESELLSCHAFT) 11 June 2003 figure 1; paragraphs</td>
<td>1-4</td>
</tr>
<tr>
<td></td>
<td>[0016] - [0023]</td>
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<tr>
<td>A</td>
<td>WO 2014/1 0039 A2 (HZO INC) 17 July 2014 entire document</td>
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<td>A</td>
<td>GB 2 446 056 A (ALSTOM TECHNOLOGY LTD) 30 July 2008 entire document</td>
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[See patent family annex.]

**Further documents are listed in the continuation of Box C.**

- *Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier application or patent but published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

- "&" document member of the same patent family

**Date of the actual completion of the international search**

27 October 2015 (27.10.2015)

**Date of mailing of the international search report**

14 JAN 2016

**Name and mailing address of the ISA/**

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

**Authorized officer**

Shane Thomas

PCT Helpdesk: 571-272-4300

PCT OIN: 571-272-7774

Form PCT/ISA/2 10 (second sheet) (January 2015)
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: claims 1-4 are directed toward a movable platform comprising an actuator configured to move the support along at least one axis relative to the pressurized dry ice.

Group II: claims 5-9 are directed toward a dry ice blasting equipment, comprising: a chamber for receiving at least one substrate.

Group III: claims 10-11 are directed toward a method for removing material from a substrate, comprising: sequentially expose a plurality of different areas of a protective coating on the at least one substrate to the pressurized dry ice.

Group IV: claims 12-29 are directed toward a material removal assembly, comprising at least one template configured to be assembled with the at least one substrate to limit exposure of the at least one substrate or a protective coating on the at least one substrate to at least one selected region.

The inventions listed as Groups I-IV do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons.

The special technical features of Group I include a movable platform for use with a material removal apparatus, comprising: a support configured to receive at least one substrate and to hold the at least one substrate in place under application of pressurized dry ice (which is not present in Group IV); and an actuator configured to move the support along at least one axis relative to the pressurized dry ice (which is not present in Groups II, III, IV).

The special technical features of Group II include a dry ice blasting equipment, comprising: a chamber for receiving at least one substrate; a nozzle within the chamber for directing pressurized dry ice toward the at least one substrate; a movable platform within the chamber configured to support the at least one substrate relative to the nozzle and to position the at least one substrate relative to the nozzle (which is not present in Groups I, III, IV); the movable platform being configured to move the at least one substrate along a plurality of axes (which is not present in Group IV).

The special technical features of Group III include directing pressurized dry ice toward the at least one substrate; and selectively moving at least one of the platen or the support plate and a nozzle from which the pressurized dry ice is ejected to sequentially expose a plurality of different areas of a protective coating on the at least one substrate to the pressurized dry ice and to enable the pressurized dry ice to remove the plurality of different areas of the protective coating from the at least one substrate (which is not present in Groups I, II, IV).

The special technical features of Group IV include a material removal assembly, comprising: at least one substrate; at least one template configured to be assembled with the at least one substrate to limit exposure of the at least one substrate or a protective coating on the at least one substrate to at least one selected region; and a fixture defining a receptacle for the template, the fixture being configured to position and/or secure the at least one substrate to a platen or a support plate of a material removal system; a method for removing material from a substrate, comprising: assembling a substrate with a template; positioning the template relative to a platen or a support plate of a material removal system; and removing a material from the substrate through at least one aperture of the template using the material removal system (which is not present in Groups I-III).

The common technical features of Groups I-IV include a movable platform for use with a material removal apparatus, comprising: a support configured to receive at least one substrate and to hold the at least one substrate in place under application of pressurized dry ice; the movable platform being configured to move the at least one substrate along a plurality of axes; and a nozzle from which the pressurized dry ice is ejected to expose a protective coating on the at least one substrate to the pressurized dry ice.

These common technical features are disclosed by EP 1317995 A1 (SIEMENS): a movable platform for use with a material removal apparatus, comprising: a support (pivoting arm extending between blade 20 and mount 22; figure 1) configured to receive at least one substrate (blade 20; figure 1) and to hold the at least one substrate in place (as shown; figure 1) under application of pressurized dry ice (dry ice jet 14; figure 1); paragraph [0023] and the movable platform being configured to move the at least one substrate along a plurality of axes (relative movement between dry ice jet 14 and pivoting arm extending between blade 20 and mount 22; figure 1; claim 10); and a nozzle (10) from which the pressurized dry ice is ejected to expose a protective coating (ceramic thermal coating; paragraph [0016]) on the at least one substrate to the pressurized dry ice.

Because the common technical features are disclosed by SIEMENS, the inventions are not so linked as to form a single general inventive concept. Therefore, Groups I-IV lack unity.