LARGE FORMAT DIE BOND PLATFORM FOR MICROLED PANEL

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relate to a LED bonding system and panels and a method of fabricating LED panels.

Description of the Related Art

[0002] A light emitting diode (LED) panel uses an array of LEDs, with individual LEDs providing the individually controllable LEDs. An LED panel that uses micron-scale LEDs based on III-V semiconductor technology (also called micro-LEDs) would have a variety of uses. LED panels for interconnect devices, such as photonic interconnect devices, include LEDs bonded to backplanes to integrate the LEDs with other components connected to the backplanes. Issues may arise during the bonding process. Process of transferring of LEDs to a backplane conventionally have low throughput. Conventional boding processes may result in poor light-up yield, thermal instability, non-uniformity, long run times, and high costs. However, there are challenges to the fabrication of micro-LED panels. Therefore, there is a need for a LED bonding system and panels and a method of fabricating LED panels.

SUMMARY

[0003] In one embodiment, a method is provided. The method includes disposing a bond head gantry over a first array of dies. The bond head gantry includes an array of bond head modules that corresponds to a respective die of the array of dies. The method also includes retaining the first array of dies with the array of bond head modules, translating, the first array of dies on to an array of elements of the backplane, aligning an array of thermal head modules over the array of bond head modules, the first array of dies, and the array of element, and applying thermal energy with the array of thermal head modules to the first array of dies through the array of bond head modules to bond the first array of dies to the array of elements to form a bonded first array.

[0004] In another embodiment, a method is provided. The method of die bonding includes disposing a bond head gantry over a first array of dies. The bond head gantry includes an array of bond head modules, wherein each bond head module of the array

of the bond head modules corresponds to a respective die of the array of dies. The method further includes retaining the first array of dies by applying a vacuum with the array of bond head modules, translating, with the bond head gantry, the first array of dies on to a first array of elements of a pattern of backplane, aligning an array of thermal head modules over a respective bond head module and a respective die of the first array of dies, applying thermal energy and bonding on to a first array of elements of the backplane to form a bonded first array. The thermal energy is applied to each die by a respective thermal head of the array of thermal head modules aligned to direct thermal energy through the respective bond head. The method further includes disposing a second array of dies on to a second array of elements of the backplane adjacent to the bonded first array with the bond head gantry.

[0005] In another embodiment, a system is provided. The bonding system includes a backplane support, a first gantry disposed over the backplane support, a bond head gantry disposed over the first gantry and coupled to a vacuum source. The bond head gantry includes an array of bond head modules having one or more bond heads. Each bond head includes an alignment mechanism and an alignment sensor. The system further includes a thermal gantry disposed over the first gantry, the thermal gantry having an array of thermal head modules having one or more thermal heads. Each thermal head includes a photonic heating element.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting of its scope, and may admit to other equally effective embodiments.

[0007] It is to be noted, however, that the drawings illustrate only exemplary embodiments of the present disclosure and are therefore not to be considered limiting of its scope, and may admit to other equally effective embodiments.

[0008] Figure 1A is a cross-sectional view of a portion of a panel according one or more embodiments.

[0009] Figure 1B is a top view of a die of a panel according one or more embodiments.

[0010] Figure 3 is a flow diagram of a method of bonding a die to a backplane according to one or more embodiments.

[0011] Figures 4-9 are schematic, top views of a bonding system during a method according to one or more embodiments.

[0012] Figure 10 is a schematic top view of a bond head according to one or more embodiments.

[0013] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

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DETAILED DESCRIPTION

[0015] Embodiments of the present disclosure generally relate to a LED bonding system and panels and a method of fabricating LED panels. The bonding system and method of fabricating LED panels described herein may be a mass transfer system and method for mass transfer of LEDs to a backplane. The method includes using a large format die bonding system with multiple gantries that apply thermal energy through optical windows within bond head modules with enhanced precision. The LED panels may be utilized for display panel devices, interconnect devices (such as photonic interconnect devices), or the like that have LEDs bonded to a backplane. The LEDs may be micro-LEDs (hereinafter, “microLEDs”). The LED panels described herein may be micro-LEDs. In some embodiments, the plurality of LEDs are disposed

in an array on the backplane. The micro-LEDs are self-emissive LEDs having a critical dimension less than 100 micrometers (μm).

[0016] Figure 1A is a cross-sectional view of a portion of a panel 105. Figure 1B is a top view of a die 100 of the panel 105. Each die 100 includes a plurality of LEDs 104. The LEDs 104 are microLEDs. The micro-LEDs are self-emissive LEDs having a critical dimension less than 100 μm. Each LED 104 includes a LED electrode 107. Each die 100 further includes one or more fiducial marks 109. The backplane 102 includes a plurality of elements 101. The elements 101 are thin film transistor (TFTs). The elements 101 are arranged in a pattern 213. The pattern 213 is an arrangement of elements 101. While, as shown in Figure 1A, each LED 104 of the die 100 is coupled to a respective element 101, each LED 104 of the die 100 may be coupled to a single element 101, i.e., single TFT. Each element 101 includes a backplane electrode 103. The backplane electrodes 103 include a metal-containing material.

[0017] The pattern 213 may also include fiducial marks such that during the methodology described herein the fiducial marks 109 of the dies 100 are aligned with the fiducial marks of the pattern 213. The fiducial marks 109 each die 100 provided for alignment to each bond head 255 (Figure 2). When the bond head 255 (Figure 2) is over the corresponding die 100, the alignment mechanism 256a and the alignment sensor 256b (Figure 2) detect the alignment of the bond head 255 in relation to the corresponding die 100. The alignment mechanism 256a and the alignment sensor 256b allow the bond head 255 to alter the orientation of the bond head 255 so the fiducial marks 1005 of the bond head 255 are aligned with the fiducial marks 109 (Figure 1B) of the die 100 and the corresponding marks of the pattern 213 (Figure 2). The alignment mechanism 256a of each bond head 255 allow for precision adjustment capabilities for real time alignment in the X, Y, and Z directions, theta rotation, co planarity, pitch, and yaw.

[0018] The LED electrodes 107 include a metal-containing material. The backplane electrodes 103 include a metal-containing material. Via the method 300 (Figure 3) using the bonding system 200, an alloy of the metal materials of each backplane electrode 103 and LED electrode 107 is formed from the thermal boding process described herein.

[0019] Figure 2 is a top view of a bonding system 200 according to some embodiments. The bonding system 200 may be used to bond the LEDs 104 to the backplane 102. (Figures 1A and 1B).

[0020] The bonding system 200 includes a bonding apparatus 201 and a backplane loader 203 coupled to the bonding apparatus 201. The backplane loader 203 includes a platform 204 configured to dispose a backplane 102 from the backplane loader 203 onto a backplane support 205 of the bonding apparatus 201.

[0021] The bonding apparatus 201 also includes one or more dies 100 disposed in one or more cassettes 211. The dies 100 may be optical device components, microLEDs, microLED chips, LED chips, but other optical device components are contemplated. The one or more dies 100 are eventually disposed within a pattern 213 of the backplane 102. In some embodiments, the pattern 213 includes individual thin film transistors (TFTs), i.e., elements 101, arranged to receive microLEDs from the dies 100. For example, the pattern 213 includes the elements 101, the backplane electrodes 103, and the fiducial marks 109 (Figure 1A and 1B).

[0022] The bonding apparatus 201 also includes a robot 215 that transfers the one or more dies 100 from the one or more cassettes 211 to a first gantry 230 coupled to a rail system 220. In some embodiments the robot 215 is one or more robotic loading arms configured to translate the die 100 from the cassette 211 to a die holder 235 of the first gantry 230. The bonding apparatus 201 may have one or more robots 215 allowed for the robots 215 to simultaneously translate multiple dies 100 from the cassettes 211 to the first gantry 230.

[0023] The rail system includes an inner rail set 221 and an outer rail set 223. The rail system 220 is also coupled to a bond head gantry 250 and a thermal gantry 270. In some embodiments, the rail system 220 is also coupled to a metrology gantry 290. For example, the metrology gantry 290 is coupled to the inner rail set 221.

[0024] The inner rail set 221 includes rails disposed on opposite sides of the backplane support 205 from each other. For example, the inner rail set 221 includes two parallel rails on opposing sides of the backplane support 205. The first gantry 230 can translate on the inner rail set 221. For example, the first gantry 230 can translate from over the backplane support 205 to past backplane support 205. When

disposed past the backplane support 205, the first gantry 230 is not directly over the backplane support 205. As illustrated in Figure 2, the robots 215 disposed the one or more dies 100 onto an array of die holders 233. The array of die holders 233 is made of individual die holders 235. Each die holder 235 is disposed on a top surface 237 of the cross member 231. The dies 100 are disposed in the array of die holders 233 to form an array of dies 217. The array of dies 217 may be a first array of dies 217, for example a linear array of dies 217.

[0025] As illustrated in Figure 2, the first gantry 230 is disposed in a receiving position, closer to the one or more cassettes 211, so that one or more robots 215 can disposed the one or more dies 100 on to a cross member 231 of the first gantry 230. The cross member 231 includes die holders 233 coupled to the cross member 231.

[0026] In some embodiments, the first gantry 230 is coupled to the inner rail set 221 and the bond head gantry 250 and the thermal gantry 270 are independently coupled to the outer rail set 223. The outer rail set 223 includes rails disposed on opposite sides of the backplane support 205 from each other. For example, the outer rail set 223 includes two parallel rails on opposing sides of the backplane support 205. In some embodiments, the outer rail set 223 is disposed parallel to the inner rail set 221. In some embodiments, the inner rail set 221 is disposed between the backplane support 205 and the outer rail set 223.

[0027] The bond head gantry 250 includes a cross member 251 with an array of bond head modules 253 formed of individual bond head modules 255. The array of bond head modules 253 are disposed on a side surface 257 of the cross member 251. The array of bond head modules 253 are each coupled to a vacuum source 252. Each individual bond head module 255 of the array of the bond head modules 253 corresponds to a respective die 100 of the array of dies 217. Each individual bond head module 255 includes and an alignment mechanism 256a and an alignment sensor 256b. The alignment mechanism 256a and the alignment sensor 256b enable each of the individual bond head modules 255 to align the respective die 100 when being retained and disposed on the backplane 102. Each alignment sensor 256b of the corresponding bond head module 255 includes alignment optics integrated with a transparent optical window that is compatible with various infrared (IR) light sources.

For example, IR lasers or IR flash sources of the thermal gantry 270. The alignment is described in more detail in the discussion of Figures 10 and 11.

[0028] The bond head gantry 250 is coupled to the outer rail set 223 so that the bond head gantry 250 while the first gantry 230 is coupled to the inner rail set 221 so both gantries can translate past each other without colliding. This enables simultaneous operations of different gantries providing improved through put over a single rail set configuration.

[0029] The thermal gantry 270 includes a cross member 271 with an array of thermal head modules 273 formed of individual thermal heads 275. Each thermal head 275 has a respective photonic heater 276 that is able to direct thermal energy toward the backplane 102. The array of thermal head modules 273 are disposed on a side surface 277 of the cross member 271. The side surface 257 of the bond head gantry 250 faces the side surface 277 of the thermal gantry 270 so that when the bond head gantry 250 is adjacent the thermal gantry 270, the array of thermal head modules 273 may be disposed over the array of bond head modules 253 without collision.

[0030] The metrology gantry 290 includes a cross member 291 with a metrology array 293 formed of individual metrology modules 295. The metrology array 293 enables metrology operations to be performed once a die 100 has been bonded to the backplane 102.

[0031] The system 200 also includes a controller 190. In some embodiments, operations of the system 200, are directed by the controller 190. The controller 190 includes a programmable central processing unit (CPU) 191 which is operable with a memory 192 (e.g., non-volatile memory) and support circuits 193. The support circuits 193 are conventionally coupled to the CPU 191 and comprise cache, clock circuits, input/output subsystems, power supplies, and the like, and combinations thereof coupled to the various components of the system 200, to facilitate control thereof. The CPU 191 is one of any form of general purpose computer processor used in an industrial setting, such as a programmable logic controller (PLC), for controlling various components and sub-processors of the processing system. The memory 192, coupled to the CPU 191, is non-transitory and is typically one or more of readily available memories such as random access memory (RAM), read only memory

(ROM), floppy disk drive, hard disk, or any other form of digital storage, local or remote.

[0032] Typically, the memory 192 is in the form of a non-transitory computer-readable storage media containing instructions (e.g., non-volatile memory), which when executed by the CPU 191, facilitates the operation of the system 200. The instructions in the memory 192 are in the form of a program product such as a program that implements the methods of the present disclosure. The program code may conform to any one of a number of different programming languages. In one example, the disclosure may be implemented as a program product stored on computer-readable storage media for use with a computer system. The program(s) of the program product define functions of the embodiments (including the methods described herein). For example, the CPU 191 causes a plurality of operations to be conducted.

[0033] Illustrative non-transitory computer-readable storage media include, but are not limited to: (i) non-writable storage media (e.g., read-only memory devices within a computer such as CD-ROM disks readable by a CD-ROM drive, flash memory, ROM chips or any type of solid-state non-volatile semiconductor memory devices, e.g., solid state drives (SSD)) on which information may be permanently stored; and (ii) writable storage media (e.g., floppy disks within a diskette drive or hard-disk drive or any type of solid-state random-access semiconductor memory) on which alterable information is stored. Such computer-readable storage media, when carrying computer-readable instructions that direct the functions of the methods described herein, are embodiments of the present disclosure. In some embodiments, the methods set forth herein, or portions thereof, are performed by one or more application specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), or other types of hardware implementations. In some other embodiments, the substrate processing and/or handling methods set forth herein are performed by a combination of software routines, ASIC(s), FPGAs and, or, other types of hardware implementations.

[0034] The controller 190 is configured to execute operations of the system 200. In some embodiments that may be combined with other embodiments, the controller 190 is configured to direct one or more of the robot 215, the first gantry 230, the bond head gantry 250, the thermal gantry 270, and the metrology gantry 290.

[0035] For example, the system 200 includes of an array of bond heads attached to the bond head gantry 250 which enables traversal along one axis to facilitate precise bonding across the entire backplane 102.

[0036] In some embodiments, the outer rail set 223 is a first X axis linear stage and the inner rail set 221 is a second X axis linear stage. The first X axis linear stage is disposed outside of the second X axis linear stage. The first X axis linear stage and the second X axis linear stage are is disposed outside of a back panel stage. The back panel stage may include heating zones.

[0037] In some embodiments, the bond head gantry 250 and the thermal gantry 270 are a first Y axis linear stage and a second Y axis linear stage. The first and second Y axis linear stages are disposed on the first X axis linear stage. The second X axis linear stage includes the first gantry 230 and the metrology gantry 290.

[0038] In some embodiments, the one or more robots 215 move microLEDs from chip cassettes to the first gantry 230. In some embodiments, the first gantry 230 is a microLED gantry that includes a slotted tray on an independent linear stage from the bond head gantry 250. The microLED gantry contains the microLED in the tray slots on an elevator allowing for continuous microLED supply during bonding operations. The microLED gantry trails the bond head modules during operation.

[0039] In some embodiments, the bonding system 200 is configured to have corresponding and respective parts. For example, a respective cassette 211e, supplies a respective die 100e. The robot 215 translates the respective die 100e and disposes the respective die 100e onto a corresponding respective die holder 235e. During operation, a respective bond head 255e extends toward, retains, and translates the respective die 100e from the respective die holder 235e and onto a respective element 101e of a respective pattern 213e of the backplane 102. During operation, a respective thermal head 275e is aligned with the respective element 101e of the backplane 102, the respective die 100e, and the respective bond head 255e to bond the respective die 100e onto the backplane 102. After the respective die 100e has been bonded to the backplane 102, the metrology gantry 290 disposed a respective metrology module 295e over the respective die 100e and performs a metrology operation on the bonded respective die 100e. These operations are described in more detail below.

[0040] In some embodiments, the bonding system 200 includes an additional bond head gantry and thermal gantry. In this embodiment, the system includes a microLED gantry, an inline metrology gantry, first and second bond head gantries, and first and second heat source gantries. The additional gantries enable enhanced throughput. The system 200 is customizable to adjust for a various number modules, gantries, backplane sizes, and desired throughput. Also, the bonding system 200 may be disposed in a nitrogen environment to enhance the quality of the inter-metallic bonding between the backplane 102 and the dies 100.

[0041] Figure 3 is a flow diagram of a method 300 of bonding the die 100 to the backplane 102 according to some embodiments. Figures 4-9 are schematic cross-sectional views of the bonding system 200 during the method 300.

[0042] At operation 301, as shown in Figure 4, the bond head gantry 250 is disposed over the array of dies 217. The backplane loader 203 has translated the backplane 102 and disposed it on the backplane support 205. The first gantry 230 has translated from the receiving position shown Figure 2 to a lift position shown in Figure 4. When in the lift position, the first gantry 230 is disposed over the backplane 102 and under the array of bond head modules 253. This enables the bond head gantry 250 to pick up the array of dies 217 from the first gantry 230 with the array of the bond head modules 253.

[0043] At operation 303, as shown in Figure 4, the bond head gantry 250 retains the first array of dies 217 with the array of bond head modules is disposed over the array of dies 217. The array of bond head modules 253 extend down toward the respective die 100 and applies a vacuum to the array of dies 217 to retain them. The vacuum is applied from the vacuum source 252 (Figure 2). After the bond head gantry 250 picks up the dies 100, the first gantry 230 is then disposed in a standby position. The bond head gantry 250 then goes into position and conducts an optical alignment process between the dies 100 and the pattern 213 at multiple predefined regions.

[0044] At operation 305, as shown in Figure 5, the bond head gantry 250 translates the array of dies 217 and disposes the array of dies 217 on elements 101 of the backplane 102. As shown in Figure 5, once the bond head gantry 250 translates the array of dies 217 from the first gantry 230, the first gantry 230 translates back to the receiving position and allows the array of bond head modules 253 to translate the

array of dies 217 onto the backplane 102. The array of bond head modules 253 dispose the array of dies 217 within the pattern 213 on the backplane 102. In some embodiments, the pattern 213 includes fiducial marks or index marks than enable the array of bond head modules 253 to dispose the array of dies 217 onto the backplane 102 with enhanced accuracy and repeatability by aligning fiducial marks or index marks of the respective bond head 255 with fiducial marks or index marks of each respective die 100 with the respective fiducial marks or index marks of the pattern 213 of the backplane 102.

[0045] At operation 307, as shown in Figure 6, the array of thermal head modules 273 of the thermal gantry 270 is aligned over the array of bond head modules 253. The thermal gantry 270 translates towards the bond head gantry 250 and disposes the array of thermal head modules 273 over the array of bond head modules 253 and over the elements 101 with the array of dies 217 disposed thereon. The thermal gantry 270 translates towards the bond head gantry 250 and disposes the array of thermal head modules 273 over the array of bond head modules 253 and the array of dies 217. After the optical alignment process, the thermal gantry 270 moves into position while the metrology gantry 290 trails the thermal gantry 270. The thermal gantry 270 performs simultaneous localized inter-metallic bonding at multiple predefined regions between the dies 100 and the backplane 102.

[0046] At operation 309, as shown in Figure 6, thermal energy is applied with the array of thermal head modules 273 to the first array of dies 217 through the array of bond head modules253. The thermal energy bonds the first array of dies 217 to the array of elements 101 of the backplane. The each thermal head 275 of the array of thermal head modules 273 is aligned over the respective bond head 255 of the array of bond head modules 253 and a respective die 100 of the first array of dies 217. In some embodiments, the thermal energy is applied by transmitting infrared light to each die 100. For example, the applying thermal energy may include directing light from a respective laser disposed within the respective thermal head 275 to a respective die 100 of the first array of dies 217. An alloy of the metal materials of each backplane electrode 103 and LED electrode 107 are formed from the thermal boding process

[0047] As shown in Figure 6 each die 100 of the array of dies 217 is bonded onto the backplane 102. Each die 100 of the array of dies 217 may be simultaneous bonded

to the backplane 102. The thermal energy directed from the respective photonic heating element 276 through the respective bond head module 255 to a respective die 100 of the first array of dies 217. In some embodiments, the active bonding area for each die 100 on the backplane 102 is typically less than a 50 millimeter by 50 millimeter square and thereby requires precise control over thermal expansion between interfaces. The bonding system 200 provides for alignment of the an array of thermal head modules 273 over the array of bond head modules 253, the first array of dies 217, and the array of elements 101 of the backplane 102 to account for the active bonding area in order to increase throughput, scalability, and efficiency in a microLED panel production process.

[0048] The thermal energy bonds the array of dies 217 to the backplane 102 and forms a first bonded array 601. The thermal energy bonds the array of dies 217 to the backplane 102 by fusing the corresponding LED electrode 107 with the respective backplane electrode 103 (Figure 1A). The individual thermal heads 275 of the array of thermal head modules 273 apply thermal energy to their respective die 100 while the array of bond head modules 253 hold the array of dies 217 in place. In some embodiments, the array of thermal head modules 273 apply thermal energy for less than 10 seconds. For example, the array of thermal head modules 273 apply thermal energy by a respective photonic heating element 276 of each thermal head 275 that transmits thermal energy through the respective bond head 255 to the corresponding die 100. In another example, thermal energy is applied by transmission of infrared light to each die 100 by a laser within the respective thermal heads 275. In some embodiments, operations 301, 303, and 305 can be performed iteratively such that a first array of dies can be bonded to the backplane 102 to form the first bonded array 601 and a second array of dies 701 (Figure 7) can be subsequently bonded to the backplane 102 adjacent the first bonded array 601 with enhanced accuracy and through put.

[0049] By applying thermal energy for a reduced period of time and selectively applying the thermal energy through the respective bond head 255, only a localized area of the respective die 100 and backplane 102 receive thermal energy, thereby reducing potential thermal mismatch. Reducing thermal mismatch allows for enhanced die bonding precision that is not limited by thermal expansion at die and backplane interfaces.

[0050] In some embodiments, the method 300 optionally includes operation 311. At operation 311, as shown in Figure 7, the bond head gantry 250 translates over a second array of dies 701 after bonding the first array of dies 217 and the metrology gantry 290 performs a metrology operation on the first bonded array 601 while the bond head gantry 250 is translating over the second array of dies 701. For example, after the localized inter-metallic bonding, the thermal gantry 270 and the bond head gantry 250 are disposed in standby positions. While in the standby position, the bond head gantry 250 picks up dies 100 from the first gantry 230 while the metrology gantry 290 is disposed in a position to scan the bonded regions that were just inter-metallically bonded. While the metrology gantry 290 performs a metrology operation, the robots 215 may be simultaneously loading the second array of dies 701 onto the first gantry 230.

[0051] As shown in Figure 8, the bond head gantry 250 translated the second array of dies 701 from the first gantry 230 to over the backplane 102. The bond head gantry 250 is able to dispose the second array of dies 701 onto the backplane 102. The second array of dies 701 is disposed adjacent the first bonded array 601. For example, the second array of dies 701 is disposed on an adjacent row and/or column of the pattern 213.

[0052] As shown in Figure 9, the backplane 102 includes a plurality of dies 100 bonded to the pattern 213 of the backplane 102 to form the panel 105 (Figure 1A). The backplane loader 203 removes the backplane 102 from the backplane support 205 so a subsequent backplane can be loaded into the apparatus 201.

[0053] Once the inline metrology gantry 290 has scanned the bonded dies 100, the inline metrology gantry is disposed in a standby positon and the bond head gantry 250 is disposed in a new position. The bond head gantry 250 in the new position, similar to the above, conducts an optical alignment process between the microLEDs and TFT arrays at multiple predefined regions.

[0054] The above process may be repeated for multiple regions across the backplane 102 until the backplane 102 has been processed and forms a bonded backplane 902, for example, the panel 105 (Figure 1A). Once the backplane 102 has been processed, all the gantries are disposed in standby positions while the

backplane loader 203 removes the bonded backplane 902 from the backplane support 205.

[0055] Figure 10 is a schematic top view of a bond head 255 according to some embodiments. the bond head 255 includes an optical window 1001 surrounded by a vacuum region 1003. The optical window 1001 includes one or more fiducial marks 1005. The fiducial marks 1005 make be index point to align the bond head 255 with the die 100 (Figure 2)

[0056] The vacuum region 1003 includes one or more vacuum ports 1007 that are connected to the vacuum source 252 (Figure 2). The one or more vacuum ports 1007 enable the individual bond heads 255 to apply a vacuum and retain the respective die 100. The applied vacuum allows the dies 100 to be picked up from the first gantry 230 (Figure 2).

[0057] The optical window 1001 may be an optically clear window or chrome masks within each bond head 255.

[0058] In some embodiments, each thermal head 275 (Figure 2) may include high frequency laser technology for rapid localized thermal bonding through by directing the thermal energy through the respective optical window 1001. The localized thermal bonding facilitates effective inter-metallic diffusion while reducing thermal expansion mismatches during operation.

[0059] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method of die bonding comprising:

disposing a bond head gantry over a first array of dies, the bond head gantry comprising an array of bond head modules, wherein each bond head module of the array of bond head modules corresponds to a respective die of the array of dies;

retaining the first array of dies with the array of bond head modules;

translating, with the bond head gantry, the first array of dies on an array of elements of a backplane;

aligning an array of thermal head modules over the array of bond head modules, the first array of dies, and the array of elements of the backplane; and

applying thermal energy, with the array of thermal head modules, to the first array of dies through the array of bond head modules to bond the first array of dies to the array of elements of the backplane to form a bonded first array.

2. The method of claim 1, wherein translating the first array of dies on the array of elements includes disposing the first array of dies on the backplane aligned with a pattern of the backplane.

3. The method of claim 1, wherein retaining the first array of dies includes applying a vacuum to the array of dies with a respective bond head, wherein each die of the array of dies is a microLED.

4. The method of claim 1, wherein the applying thermal energy includes directing thermal energy from a photonic heating element within each thermal head of the array of thermal head modules, the thermal energy directed from a respective photonic heating element through a respective bond head module to a respective die of the first array of dies.

5. The method of claim 1, further comprising:

loading a second array of dies onto a first gantry after translating the first array of dies onto the backplane.

6. The method of claim 1, further comprising:

aligning a first fiducial mark of each die of the first array of dies with a respective fiducial mark of the backplane.

7. The method of claim 1, wherein the thermal energy is applied through an optical window of each bond head.

8. The method of claim 1, further comprising:

performing a metrology operation on the bonded first array with a metrology gantry while translating the bond head gantry toward a second array of dies; and

translating a thermal gantry comprising the array of thermal head modules away from the bonded first array.

9. The method of claim 1, wherein the thermal energy is applied by transmitting infrared light to each die.

10. A method of die bonding comprising:

disposing a bond head gantry over a first array of dies, the bond head gantry comprising an array of bond head modules, wherein each bond head module of the array of bond head modules corresponds to a respective die of the array of dies;

retaining the first array of dies by applying a vacuum with the array of bond head modules;

translating, with the bond head gantry, the first array of dies on to a first array of elements of a pattern of backplane;

aligning an array of thermal head modules over a respective bond head module and a respective die of the first array of dies;

applying thermal energy to bond each die of the first array of dies on to a first array of elements of the backplane to form a bonded first array, the thermal energy applied to each die by a respective thermal head of the array of thermal head modules, the respective thermal head aligned to direct thermal energy through the respective bond head; and

disposing a second array of dies on to a second array of elements of the backplane adjacent to the bonded first array with the bond head gantry.

11. The method of claim 10, wherein the applying thermal energy further comprises:

directing light from a respective laser disposed within the respective thermal head to a respective die of the first array of dies, the respective thermal head aligned over the respective bond head and the respective die so the respective laser directs the thermal energy through a respective optical window of each bond head module.

12. The method of claim 10, further comprising:

translating one or more dies from a cassette to a die holder coupled to a first gantry with a robot to form the first array of dies; and

translating one or more dies from the cassette to the die holder coupled to the first gantry with the robot to form the second array of dies.

13. The method of claim 10, further comprising:

translating the bond head gantry over the second array of dies after bonding the first array of dies; and

performing a metrology operation on the bonded first array with a metrology gantry while translating the bond head gantry over the second array of dies.

14. A bonding system comprising:

a backplane support;

a first gantry disposed over the backplane support;

a bond head gantry disposed over the first gantry and coupled to a vacuum source, the bond head gantry comprising:

an array of bond head modules having one or more bond heads, each bond head comprising:

an alignment mechanism; and

an alignment sensor; and

a thermal gantry disposed over the first gantry, the thermal gantry comprising:

an array of thermal head modules having one or more thermal heads, each thermal head comprising a photonic heating element.

15. The bonding system of claim 14, further comprising:

a metrology gantry disposed over the backplane support.

16. The bonding system of claim 14, further comprising:

a rail system coupled to the first gantry, the bond head gantry, and the thermal gantry.

17. The bonding system of claim 16, wherein the rail system comprises:

an outer rail set coupled to the bond head gantry and the thermal gantry; and

an inner rail set coupled to the first gantry, the inner rail set disposed between the backplane support and the outer rail set.

18. The bonding system of claim 14, wherein the photonic heating element is a laser.

19. The bonding system of claim 14, further comprising:

a robotic loading arm configured to translate a die from a cassette to a die holder of the first gantry.

20. The bonding system of claim 14, wherein each of the one or more bond heads is coupled to the vacuum source.