

Apparatus for dispensing a solder wire

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Technical Field

The present invention relates to an apparatus for dispensing solder a wire on a substrate.

Prior-Art

15 From the state-of-the-art, various apparatus and components are known for dispensing a solder, for example as cited below.

US 10399170 B2 describes a die attachment apparatus for attaching a semiconductor die on a substrate having a metallic surface comprises a material dispensing station for dispensing a bonding material on the substrate
20 and a die attachment station for placing the semiconductor die on the bonding material which has been dispensed on the substrate. An activating gas generator positioned before the die attachment station introduces activated forming gas on the substrate in order to reduce oxides on the substrate.

EP 1393545 B1 describes a method and device for applying solder to a
25 substrate involving melting a solder wire in a mixing chamber and feeding it into a flow of gas and moving or lowering a two medium nozzle relative to the substrate so as to deposit solder blown out of the nozzle on the substrate. The solder wire is fed to the mixing chamber in a guide tube and its end is retracted into the guide tube to interrupt the deposition process.

US 5065932 a nozzle assembly is shown for depositing solder on a series of conductive surfaces such as the mounting pads of a surface mount integrated circuit board. The nozzle assembly includes a nozzle head which has an interior bore for receiving an elongated heat source. The nozzle head also
5 includes an orifice for receiving solid solder fed within the interior bore to contact the elongated heat source. The interior bore terminates in a solder reservoir for molten solder which is fed within the interior bore to contact the elongate heat source. The molten solder is dispensed through a tip opening to deposit uniform amounts of solder on each pad. A source of bleed gas is
10 supplied to the interior of the assembly to protect the component parts and exclude oxygen from the interior of the assembly. A cover gas is also supplied to the solder site to reduce oxidation of the molten solder and reduce the amount of flux required.

In general, the control of conventional solder dispensing processes require
15 complex and multiple functionalities, with a plurality of nozzles and gas flows, to ensure that the solder is melting, or not melting at intended positions with intended timings. In addition, multiple gas flows and gas mixtures may further increase the complexity and cost of apparatus operation.

Content of the Invention

20 An objective of the invention is therefore to provide a solder dispenser providing additional functionality without increasing complexity.

According to the invention, an apparatus is provided for dispensing a solder wire on a substrate, the apparatus comprising a dispensing body, a dispensing channel for the solder wire, extending through the dispensing body, configured
25 and arranged to receive the solder wire at a first end and to dispense the solder wire from a second end facing the substrate, and a first cooling chamber, configured and arranged to cool a region of the solder wire with a first cooling gas within the dispensing channel, wherein the first cooling chamber comprises at least one inlet for the first cooling gas, a wire-facing outlet for the
30 first cooling gas and a dispensing outlet for the first cooling gas, whereby the

first cooling chamber is configured and arranged to allow, in use, the first cooling gas to enter the first cooling chamber through the at least one inlet for the first cooling gas, to pass out of the wire-facing outlet for the first cooling gas away from the substrate, and to pass out of the dispensing outlet for the first cooling gas towards the substrate; and wherein the dispensing channel for the solder wire is comprised within the first cooling chamber. By providing a direct flow of the first cooling gas to the solder wire, unwanted variations in process results may be reduced, and the dispensing apparatus may be made less complex. Operational costs may also be reduced due to minor gas consumption.

Mode for Carrying out the Invention

An embodiment of an apparatus are designed and embodied such way that the first cooling chamber and the dispensing channel for the solder wire have similar or the same dimensions in one or more regions inside the dispensing body. This may reduce mechanical complexity, weight and/or volume, by allowing a single structure, such as a single bore, to be configured as a significant portion of both the dispensing channel and the cooling chamber.

Embodiments of an apparatus are designed and embodied such way that the dispensing outlet has similar or the same dimensions as the second end of the dispensing channel. Additionally or alternatively, the wire-facing outlet has similar or the same dimensions as the first end of the dispensing channel. This may further reduce mechanical complexity, weight and/or volume.

Embodiments of an apparatus are designed and embodied such way that the apparatus further comprises at least one auxiliary outlet for the first cooling gas, disposed outside the dispensing body, configured and arranged to allow, in use, at least a portion of the first cooling gas to pass from the first cooling chamber towards the substrate. This may increase the effectiveness of the wire cooling, due to cooling effects acting even after the wire has left the apparatus.

Embodiments of an apparatus are designed and embodied such way that the first cooling gas comprises nitrogen, carbon dioxide, helium, neon, argon, krypton, hydrogen, carbon monoxide or any combination thereof. This avoids or reduces oxidation and related effects thereof of the substrate due to cooling gas.

Embodiments of an apparatus are designed and embodied such way that the first cooling gas comprises nitrogen and 5% to 20% of hydrogen. This allows low operational costs and a good protective atmosphere for the wire and the substrate due to reduced substrate and wire oxidation

10 Embodiments of an apparatus are designed and embodied such way that the first cooling gas passing through the dispensing outlet has a flow in the range of 0.1 to 5 liters per minute. This range of values allows an effective cooling of the wire. In particular, additional thermal effects on the substrate can be reduced or avoided within this range.

15 Embodiments of an apparatus are designed and embodied such way that the first cooling gas passing through the wire-facing outlet has a flow in the range of 0.1 to 5 liters per minute. This range of values allows an effective cooling of the wire while minimizing the cooling effects on the substrate.

Embodiments of an apparatus are designed and embodied such way that the at least one inlet for the first cooling gas is disposed at an angle of less than 90 degrees in a counter-clockwise direction to the longitudinal axis of the dispensing body if viewed in a longitudinal cross-section through the dispensing body and the at least one inlet for the first cooling gas. This allows the first cooling gas to flow in an optimal ratio through the wire-facing outlet and the dispensing outlet, averting oxygen from entering the nozzle but keeping a high cooling effectiveness.

Embodiments of an apparatus are designed and embodied such way that the at least one inlet for the first cooling gas is disposed at an angle of 30 degrees or more in a counter-clockwise direction to the longitudinal axis of the

dispensing body if viewed in a longitudinal cross-section through the dispensing body and the at least one inlet for the first cooling gas.

Embodiments of an apparatus are designed and embodied such way that, in use, an average temperature of the first cooling gas in at least a portion of the first cooling chamber is predetermined and/or controlled to be 50 degrees Celsius or more below an average melting point of the solder wire. This prevents wire melting inside the apparatus.

Embodiments of an apparatus are designed and embodied such way that the apparatus further comprising a second cooling chamber, configured and arranged to cool a region of the dispensing body with a second cooling gas, wherein the second cooling chamber comprises at least one inlet for the second cooling gas, and at least one outlet for the second cooling gas, whereby the second cooling chamber is configured and arranged to allow, in use, the second cooling gas to enter the second cooling chamber through the at least one inlet for the second cooling gas, and to pass out of the at least one outlet for the second cooling gas. The second cooling chamber allows more process settings for the cooling. Depending on the material, it might be beneficial for the soldering result if the second cooling is applied in addition to the first cooling or exclusively.

Embodiments of an apparatus are designed and embodied such way that the apparatus further comprising at least one auxiliary outlet for the second cooling gas, disposed outside the dispensing body, configured and arranged to allow, in use, the second cooling gas to pass from the second cooling chamber towards the substrate. This allows the second cooling gas to flow without influencing the process on the substrate.

Embodiments of an apparatus are designed and embodied such way that the second cooling gas comprises nitrogen, carbon dioxide, helium, neon, argon, krypton, hydrogen, carbon monoxide, oxygen, air or any combination thereof.

Embodiments of an apparatus are designed and embodied such way that the second cooling gas and the first cooling gas are the same. This may reduce mechanical and operational complexity.

Further advantages and characteristics of the invention result from the following figures, namely:

FIG. 1A depicts a longitudinal cross-section through an apparatus for dispensing solder wire showing a first cooling function; and

FIG. 1B depicts a longitudinal cross-section through an apparatus for dispensing solder wire showing an optional second cooling function.

10 **Detailed description of the invention**

FIG. 1A depicts a longitudinal cross-section through an apparatus 100 for dispensing a solder wire 200 on a substrate 500, showing a first cooling function. For clarity, only the first cooling function is depicted. The optional second cooling function is depicted in FIG. 1B, described in more detail below.

15 More particularly, FIG. 1A depicts the apparatus 100 comprising a dispensing body 300 and a dispensing channel 400 for the solder wire 200, extending through the dispensing body 300. In other words, the dispensing channel 400 is comprised within the dispensing body 300. The dispensing channel 400 is configured and arranged to receive the solder wire 200 at a first end 430 and
20 to dispense the solder wire 200 from a second end 470 facing the substrate 500. The apparatus 100 may be configured and arranged to operate with any suitable type of a solder wire 200.

The apparatus 100 further comprises a first cooling chamber 600, configured and arranged to cool a region of the solder wire 200 with a first cooling gas
25 810 within the dispensing channel 400. The dispensing channel 400 for solder wire 200 is comprised within the first cooling chamber 600 – this allows a flow of the first cooling gas 810 to be provided, in use, around the solder wire 200 within the dispensing body.

More particularly, the first cooling chamber 600 comprises at least one inlet 630 for the first cooling gas 810, a wire-facing outlet 651 for the first cooling gas 810 and a dispensing outlet 652 for the first cooling gas 810.

FIG. 1A depicts a longitudinal cross-section through the dispensing body 300
5 and the at least one inlet 630 for the first cooling gas 810.

The first cooling chamber 600 is configured and arranged to allow, in use, the first cooling gas 810 to enter the first cooling chamber 600 through the at least one inlet 630 for the first cooling gas 810, to pass out of the wire-facing outlet 651 for the first cooling gas 810 away from the substrate 500, and to pass out
10 of the dispensing outlet 652 for the first cooling gas 810 towards the substrate 500. This allows a flow of the first cooling gas 810 to be provided around the solder wire 200 away from the substrate 500 towards the region where the solder wire 200 is received for dispensing. Additionally, this allows a flow of the first cooling gas 810 to be provided around the solder wire 200 in the region
15 towards the substrate 500.

The apparatus 100 is configured and arranged to provide a flow of the first cooling gas 810 around the solder wire 200 during use. Optionally, it may be advantageous to provide a flow of the first cooling gas 810 around the solder wire 200 in substantially all of the dispensing channel 400. Additionally or
20 alternatively, it may be advantageous to provide a continuous flow of the first cooling gas 810 during a period of time. Alternatively, it may be advantageous to provide a pulsed flow of the first cooling gas 810 during a period of time.

During use, the first cooling gas 810 is connected to the at least one inlet 630 for the first cooling gas 810, whereby it enters the first cooling chamber 600,
25 which comprises the dispensing channel 400.

The first end 430 which receives the solder wire 200 is disposed at the wire-facing outlet 651 for the first cooling gas 810. The second end 470 for the first cooling gas 810 is disposed at the dispensing outlet 652 for the first cooling gas 810.

The dispensing channel 400 are the one or more regions immediately proximate, in use, to the solder wire 200, extending from the first end 430 to the second end 470. The cooling chamber 600 comprises the dispensing channel 400 by including one or more regions with dimensions greater than or equal to the dimensions of the respective region of the dispensing channel 400.

Optionally, it may be advantageous if the apparatus 100 is configured such that the first cooling chamber 600 and the dispensing channel 400 for the solder wire 200 have similar or the same dimensions in one or more regions inside the dispensing body 300. For example, as depicted in FIG. 1A and 1B, a single structure, such as a single bore through the dispensing body 300, may be configured and arranged as a significant portion of both the cooling chamber 600 and the dispensing channel 400. This may reduce mechanical complexity, weight and/or volume.

Additionally or alternatively, the dispensing outlet has similar or the same dimensions as the second end of the dispensing channel. Additionally or alternatively, the wire-facing outlet has similar or the same dimensions as the first end of the dispensing channel. This may further reduce mechanical complexity, weight and/or volume.

The flow of the first cooling gas 810 into the dispensing channel 400 is divided into two main flows around the solder wire 200: a first main flow 8101 towards the substrate 500, leaving the dispensing channel 400 at the second end 470 of the dispensing channel 400, and a second main flow 8102 away from the substrate 500, leaving the dispensing channel 400 at the first end 430 of the dispensing channel 400.

The second main flow 8102 may be configured and arranged to reduce the risk of environmental contamination of at least a portion of the dispensing channel 400. In particular, it may be advantageous to avoid oxygen contamination of at least a portion of the dispensing channel 400.

The second main flow 8102 may be further advantageous as it allows the apparatus 100 to be configured and arranged to provide the first cooling gas 810 around the solder wire 200 in substantially all of the dispensing channel 400.

- 5 For example, the apparatus 100 may be configured and arranged to provide, in use, the first cooling gas 810 passing through the dispensing outlet 652 with a first main flow 8101 in the range of 0.1 to 5 liters per minute (l/min).

Additionally or alternatively, the apparatus 100 may be configured and arranged to provide, in use, the first cooling gas 810 passing through the wire-
10 facing outlet 651 with a second main flow 8102 in the range of 0.1 to 5 liters per minute (l/min).

The apparatus 100 may be configured and arranged to be used in a soft-solder process, where the solder wire 200 is to be provided to a substrate 500, such as a lead-frame. Optionally, during or after dispensing, the dispensed solder
15 250 may be pressed and/or stamped (optionally with a further apparatus) to provide a larger surface area. Optionally, a predetermined and/or controlled shape may be formed, such as a rectangle or square. Subsequently, a die may be bonded on the upper surface of the dispensed solder 250. This result is an intermetallic bond between the lead-frame substrate 500 and the die. Typically,
20 such a soft-solder process takes place at a temperature of approximately 380 degrees Celsius (°C).

The invention is at least partially based on the insight that conventional dispensing apparatus that rely on indirect cooling are inefficient. The cooling is considered indirect if a cooling gas is provided which does not come into
25 direct contact with the solder wire. In other conventional apparatus, where a forming gas is to be applied, a separate gas distribution system, usually with dedicated gas outlets, is used to convey the forming gas close to solder on the substrate surface 500 during and/or after dispensing.

Providing a configurable flow of the first cooling gas 810 around the solder wire
30 200 may be advantageous due to a higher cooling efficiency. This may reduce

process parameter variations which would in turn provide a more consistent and repeatable dispensed solder 250. Consistency and/or repeatability may be evaluated, for example, by using one or more characteristics such as: a shape, a dimension, a curvature, a volume, an area, a wetting angle, an absolute position on the substrate 500, a relative position on the substrate 500, or any combination thereof.

The invention is also at least partially based on the insight that in conventional dispensing apparatus relying on indirect cooling, a relatively high flow is required to provide stable and reliable dispensing in a controlled manner. High gas flow settings are required, such as more than 20 liters per minute (l/min), which may increase operational costs.

Further, many conventional apparatus use gas flow primarily to reduce the risk of oxidation in regions proximate the substrate. However, the invention is also at least partially based on the insight that direct cooling of the solder wire 200 in the dispensing channel 400 is more advantageous.

In general, those conventional dispensing apparatus and dispensing nozzles are relatively complex, making them expensive to manufacture. The inventors have determined experimentally that those complex apparatus may show unwanted leakage of indirect cooling gas in case of operating with relatively high flow rates. Conventionally, the person skilled in the art have attempted to reduce unwanted leakage by, for example, reducing dimensional tolerances and/or mechanical stress in the mechanical parts of the apparatus, and sealing using high-temperature ceramic pastes.

By providing a direct flow of the first cooling gas 810 to the solder wire 200 according to the invention, unwanted variations in process results may be reduced.

In some apparatus 100, the required flow of the first cooling gas 810 may be reduced. In some apparatus 100, that may reduce the operational costs by reducing the cooling gas consumption. This may also reduce the complexity of the solder dispensing apparatus 100.

In some apparatus 100, a weight and/or a volume of the solder dispensing apparatus 100 may be reduced.

Any suitable gas, gas composition or gas mixture may be used as a first cooling gas 810 for the process being performed – for example, the first cooling gas 810 may comprise nitrogen, carbon dioxide, helium, neon, argon, krypton, hydrogen, carbon monoxide or any combination thereof.

Additionally or alternatively, the first cooling gas 810 may comprise nitrogen and 5% to 20% of hydrogen.

Optionally, the apparatus may be configured and arranged to provide the first cooling gas 810 such that, in at least a portion of the first cooling chamber 600, an average temperature is predetermined and/or controlled to be 50°C or more below an average melting point of the solder wire 200. For example, the apparatus 100 may further comprise one of more coolers (not depicted) fluidly before or immediately before the at least one inlet 630 for the first cooling gas 810. For example, the melting point temperature of solder 200 lies typically in the range of 300°C to 400°C. In some specialized processes, melting point temperatures may reach up to 1000°C.

It may also be advantageous to provide the first cooling gas 810 such that, in substantially all of the dispensing channel 400, an average temperature is predetermined and/or controlled to be 50°C or more below an average melting point of the solder wire 200.

Optionally, the first cooling gas 810 may be provided such that, in a region proximate the dispensing outlet 652, an average temperature is predetermined and/or controlled to be 50°C or more below an average melting point of the solder wire 200.

For example, in case of dispensing the solder wire 200 with a melting point in the range of 300°C to 400°C, the first cooling gas 810 may be provided such that an average temperature is predetermined and/or controlled to be in the

range of 100°C to 150°C when measured, in an idle mode, approximately 1mm away from the dispensing outlet 652.

FIG. 1B depicts a longitudinal cross-section through the apparatus 100 as showing a second optional cooling function. The apparatus 100 depicted in
5 FIG. 1B is the same as the apparatus depicted in FIG. 1A and described in relation to FIG. 1A. However, for clarity reasons, a number of features depicted in FIG. 1A are not shown in FIG. 1B. This second optional cooling function is indirect, and configured and arranged to operate simultaneously with the first cooling function.

10 In particular, FIG. 1B depicts the apparatus 100 comprising a second cooling chamber 700, configured and arranged to cool a region of the dispensing body 300 with a second cooling gas 820.

The second cooling chamber 700 comprises at least one inlet 730 for the second cooling gas 820, and at least one outlet 750 for the second cooling gas
15 820. The second cooling chamber 700 comprises at least one outlet 750. Any suitable number of outlets 750 may be used. For example, FIG. 1B depicts two outlets 750 for the second cooling gas 820. Optionally, a modified mechanical construction may be used to provide only one outlet 750 for the second cooling gas 820.

20 So, FIG. 1B depicts a longitudinal cross-section through the dispensing body 300, the at least one inlet 630 for the first cooling gas (not indicated), the at least one inlet 730 for the second cooling gas 820, and two outlets 750 for the second cooling gas 820. FIG. 1B depicts one example - the skilled person will realize that the inlets and outlets do not need to be disposed within the same
25 longitudinal cross-section.

The second cooling chamber 700 is configured and arranged to allow, in use, the second cooling gas 820 to enter the second cooling chamber 700 through the at least one inlet 730 for the second cooling gas 820, and to pass out of the at least one outlet 750 for the second cooling gas 820.

Optionally, the second cooling gas 820 passing out of the at least one outlets 750 may be directed away from the substrate 500.

Any suitable gas, gas composition or gas mixture may be used as a second cooling gas 820 for the process being performed – for example, the second cooling gas 820 may comprise nitrogen, carbon dioxide, helium, neon, argon, krypton, hydrogen, carbon monoxide, oxygen, air or any combination thereof.

The second cooling function is optional. It may be configured and arranged separately from the first cooling function. Alternatively, the second cooling function may be configured and arranged to co-operate with the first cooling function to achieve a required degree of cooling.

The first cooling function may be configured and arranged separately from the optional second cooling function. Alternatively, if the optional second cooling function is provided, the first cooling function may be configured and arranged to co-operate with the second cooling function to achieve a required degree of cooling.

As depicted in FIG. 1A and described above, the first cooling function comprises a flow of the first cooling gas 810 into the dispensing channel 400 which is divided into a first main flow 8101 towards the substrate 500, and a second main flow 8102 away from the substrate 500.

As depicted in FIG. 1A, the apparatus 100 may be optionally further configured and arranged to dispose the at least one inlet 630 for the first cooling gas 810 at an angle 950 of less than 90 degrees, in a counter-clockwise direction, to the longitudinal axis 900 of the dispensing body 300 if viewed in a longitudinal cross-section through the dispensing body 300 and the at least one inlet 630 for the first cooling gas 810. The angle 950 of the at least one inlet 630 may be determined using an axis of symmetry 920 of the at least one inlet 630. This angle 950 may be predetermined and/or controlled to modify the flow ratio between the first main flow 8101 towards the substrate 500, and the second main flow 8102 away from the substrate 500.

For example, it may be advantageous where the angle 950 is in the range between 30 degrees and 90 degrees.

For example, it may be further advantageous where the angle 950 is in the range between 70 degrees and 90 degrees.

- 5 Predetermining and/or controlling this angle 950 may modify the ratio between the first main flow 8101 towards the substrate 500 and the second main flow 8102 away from the substrate 500. For example, at an angle 950 of approximately 90 degrees, the ratio may be approximately 1:1. For example, reducing the angle 950 to significantly less than 90 degrees may relatively
10 increase the first main flow 8101 towards the substrate 500, while maintaining a second main flow 8102 of sufficient volume to reduce the risk of environmental contamination into at least a portion of the dispensing channel 400 through openings such as the wire-facing outlet 651.

- The inventors have determined that the use of direct cooling (the first cooling
15 function) according to the invention may provide at least a comparable degree of processing quality compared to conventional methods using only indirect cooling.

- For these measurements, the apparatus 100, as depicted in FIG. 1A and 1B, was implemented by modifying a conventional type of wire dispenser
20 apparatus suitable for a soft-solder process. The conventional indirect cooling function of the conventional wire dispenser apparatus was configured and arranged as the second cooling function depicted in FIG. 1B and described in this disclosure. A direct cooling function was added to the wire dispenser apparatus, and configured and arranged as the first cooling function depicted
25 in FIG. 1A and described in this disclosure.

- Embodiments of a wire dispenser apparatus may comprise an inlet distributor 670 for the first cooling gas 810, fluidly connected to the dispensing channel 400. In this example, the first cooling chamber 600 and the dispensing channel 400 may have similar or the same dimensions in one or more regions inside
30 the dispensing body 300.

Embodiments of a wire dispenser apparatus may dispose the at least one inlet 630 for the first cooling gas 810 at an angle 950 of approx. 70 degrees in a counter-clockwise direction to the longitudinal axis 900 of the dispensing body 300 if viewed in a longitudinal cross-section through the dispensing body 300 and the at least one inlet 630 for the first cooling gas 810.

Embodiments of a wire dispenser apparatus may retain the original dispensing channel 400 with an average bore diameter of 0.4 to 1.2 mm, for use with a solder wire 200 having an average diameter in the range of 0.2 to 1.0 mm.

To measure relative performance, representative process results were selected for the comparison: the average volume of dispensed solder in cubic millimeters (mm³), the variation calculated as the standard deviation divided by the average volume in percentage (%) and the wire slippage in microns (μm).

Both the first (direct) and second (indirect) cooling functions were connected using flow regulators to investigate the impact of different flow regimes. It was assumed that the measurements made with a flow solely through the second cooling function (measurements no. 01 to 03) were an acceptable approximation of the operation using an unmodified conventional wire dispenser apparatus.

Measurements (Table 1):

No.	Flow into second (indirect) cooling function	Flow into first (direct) cooling function	Average volume of dispensed solder	Variation	Wire slippage
	[lit/min]	[lit/min]	[mm ³]	[StDev / ave volume]	[μm]
01	25	0	0.583	1.47%	22.729
02	10	0	0.575	1.46%	35.613
03	3	0	0.555	2.72%	26.823
04	1	0.5	0.590	1.51%	30.686

05	0	0.8	0.560	1.34%	27.804
06	0	0.6	0.566	1.61%	24.902
07	0	0.6	0.554	1.79%	26.739
08	0	0.4	0.581	1.89%	34.299
09	0	0.6	0.574	1.77%	27.805
10	0	0.5	0.549	1.88%	34.180
11	0	0.5	0.582	1.75%	29.920

Measurements 01 to 03 were made solely with indirect cooling using the second cooling function, as an acceptable approximation of the situation using a conventional wire dispense apparatus. Measurement 01 may be considered to represent standard operating conditions for a soft-solder process using the conventional wire dispense apparatus.

By comparison, measurement 04 was made with a small degree of indirect cooling, and direct cooling with the first cooling function.

By comparison, measurements 05 to 11 were made with direct cooling only.

The measurement results of Table 1 show that in case of a variation of the indirect cooling flow from a typical rate of 25 l/min to 3 l/min as provided by measurements 01 to 03, a significant increase (worsening) in variation to 2.72% is observable at an indirect cooling flow rate of 3 l/min as provided by measurement 03. This corresponds to an approximately 90% reduction in the indirect flow rate compared to the standard operating conditions of measurement 01.

In case of a reduction of the indirect cooling to 1 l/min, a direct cooling of 0.5 l/min as provided by measurement 04, and the variation drops again to 1.51%, which is comparable to the standard operating conditions of measurement 01, whereas the drop of the variation represents a direct improvement.

And in case of an increase of the direct cooling rate to 0.8 l/min, a drop in the variation of 1.3% is observable at measurement 05, which is a lower variation that can be measured under the standard operating conditions of

measurement 01, whereas the drop of the variation represents a direct improvement.

In case of a direct-only cooling flow of 0.6 l/min as observable at measurements 06, 07, 09, the measurement results show some fluctuations
5 in the variation of 1.61% to 1.71%.

In case of a direct-only cooling flow of 0.5 l/min as observable at measurements 10 and 11, the measurement results show some fluctuations in the variation of 1.75% to 1.88%. Comparing to measurement 04 where an additional indirect cooling is provided of 1 l/min shows that further improvement
10 in the process quality may be expected in case of indirect cooling being used in addition to direct cooling.

Measurements 04 and 05 show a slightly improved level of variation compared to the standard operating conditions of measurement 01, but with a lower total gas usage. In particular, for measurement 04 with 0.5 l/min direct cooling and
15 1 l/min indirect cooling, the total usage was 1.5 l/min, which was a reduction of 94% in usage compared to measurement 01. In particular, for measurement 05 with 0.8 l/min direct cooling only, the total usage was 0.8 l/min, which was a reduction of approximately 95% in usage compared to measurement 01.

In addition, the skilled person will realize that wire slippage remains relatively
20 unchanged during direct-only cooling, combined direct and indirect cooling and indirect-only cooling.

Gas temperatures and degrees of cooling may be predetermined and/or controlled using parameters for direct and/or indirect cooling such as gas flow, gas composition, gas mixture, chamber dimensions, inlet dimensions, outlet
25 dimensions, channel dimensions, or any combination thereof.

By following the instructions provided in this disclosure, one or more embodiments of the wire dispensing apparatus 100 including a direct cooling flow of the first cooling gas 810 may be optimized to further improve a solder dispensing procedure. For example, it may be advantageous to optimize the

embodiments to improve to improve the protection of the (200) during use and an increased degree of cleaning of the solder wire (200) from potentially present oxides.

5 Additionally or alternatively, it may be advantageous to optimize one or more embodiments to provide less friction and less slippage of the solder wire 200 in the dispensing channel 400. In this example, the solder wire 200 may be considered to be contained in a gas bearing system due to the dispensing channel 400 being filled with the first cooling gas 810.

10 Additionally or alternatively, it may be advantageous to optimize one or more embodiments to provide less clogging of the solder wire 200 by expelling solder particles and/or other contamination from the dispensing outlet 652.

15 Additionally or alternatively, it may be advantageous to optimize one or more embodiments to provide less cleaning of the dispensing channel 400 by expelling solder particles and/or other contamination out through the wire-facing outlet 651 and/or the dispensing outlet 652.

20 Additionally or alternatively, it may be advantageous to optimize one or more embodiments to provide a more reliable and repeatable dispensed solder by optimizing for a low wetting angle below 40 degree, preferably below 35 degree, and most preferably below 30 degree and/or a reduced volume variation of less than approximately 5 percent standard deviation, preferably less than approximately 2 percent standard deviation, and most preferably less than approximately 1 percent standard deviation of the volume of the dispensed solder.

25 Additionally or alternatively, it may be advantageous to optimize one or more embodiments to provide an improved dispensed solder 250 (or dot) placement accuracy.

Optionally, the apparatus 100 may further comprise at least one auxiliary outlet (not depicted) for the first cooling gas 810, disposed outside the dispensing body 300. This may be configured and arranged to allow, in use, at least a

portion of the first cooling gas 810 to pass from the first cooling chamber 600 towards the substrate 500.

The at least one auxiliary outlet may be further configured and arranged to direct at least a portion of the first cooling gas 810 towards the substrate 500 at an angle that is: substantially parallel to a longitudinal axis 900 of the dispensing body 300 with no or a minimal deviation of less than 1.0 or less than 2.0 degrees from the axis, significantly not parallel to the longitudinal axis 900, at a non-zero angle to the longitudinal axis 900, or any combination thereof. In some configurations, it may be advantageous to direct at least a portion of the first cooling gas 810 towards the substrate 500 at an angle that is: approximately perpendicular to the longitudinal axis 900. These are angles if viewed in a longitudinal cross-section through the dispensing body 300 and the at least one auxiliary outlet for the first cooling gas 810. Preferably, the at least one auxiliary outlet is arranged in one or more positions, concentrically and symmetrically transversely disposed with respect to the longitudinal axis 900. In other words, the arrangement may resemble a "shower head" for the first cooling gas 810 if the second end 470 of the solder dispensing channel 400 is viewed from the substrate 500. This may provide one or more approximately concentric flow regions of first cooling gas 810 around the wire 200 and/or dispensed solder 250. Parameters such as a shape, a dimension and a number of the at least one outlet may vary depending on the process being carried out.

Embodiments may also be considered advantageous, either on their own or in combination with one or more of the other examples.

For example, it may be advantageous to modify a conventional dispensing channel, such as a wire dispense apparatus, by adding at least one inlet for a first cooling gas 810 fluidly connected to the original dispensing channel and/or wire capillary.

For example, it may be advantageous to provide one or more gas flow controllers for the first cooling gas 810, to allow the apparatus, user, operator, or any combination thereof, to control a flow of the first cooling gas 810.

- For example, it may be advantageous to provide one or more through-holes
5 between the at least one inlet 630 for the first cooling gas 810 and the dispensing channel 400 to predetermine a significant degree of the flow within the dispensing chamber 400. These through-holes may be arranged in any suitable arrangement and configuration – for example, a plurality of through-holes may be provided in an inlet distributor 670 (as depicted in FIG. 1A).
10 Preferably, the inlet distributor 670 is configured and arranged to provide the flow substantially all around the outside of the solder wire 200.

For example, it may be advantageous to provide one or more flow meters to measure the strengths of at least a portion of one or more flows of the first cooling gas 810.

- 15 For example, it may be advantageous to provide one or more flow meters to measure the strengths of at least a portion of one or more flows of the second cooling gas 820.

Reference number list

No.	Definition
100	wire dispensing apparatus
200	solder wire
250	dispensed solder
300	dispensing body
400	solder wire dispensing channel
430	first end of a solder dispensing channel
470	second end of a solder dispensing channel
500	substrate
600	first cooling chamber
630	inlet for a first cooling gas
651	wire-facing outlet for a first cooling gas
652	dispensing outlet for a first cooling gas
670	inlet distributor for a first cooling gas
700	second cooling chamber
730	inlet for a second cooling gas
750	outlet for a second cooling gas
810	first cooling gas
8101	first main flow of a first cooling gas (towards a substrate)
8102	second main flow of a first cooling gas (away from a substrate)
820	second cooling gas
900	longitudinal axis
920	axis of symmetry of a first cooling gas inlet
950	angle of a gas inlet

Patent Claims

1. Apparatus (100) for dispensing a solder wire (200) on a substrate (500),
the apparatus (100) comprising:
 - a dispensing body (300);
 - 5 - a dispensing channel (400) for the solder wire (200), extending
through the dispensing body (300), configured and arranged to
receive the solder wire (200) at a first end (430) of the
dispensing channel (400) and to dispense the solder wire (200)
10 from a second end (470) of the dispensing channel (400) facing
the substrate (500); and
 - a first cooling chamber (600), configured and arranged to cool
a region of the solder wire (200) with a first cooling gas (810)
within the dispensing channel (400);

wherein the first cooling chamber (600) comprises at least one inlet
15 (630) for the first cooling gas (810), a wire-facing outlet (651) for the first
cooling gas (810) and a dispensing outlet (652) for the first cooling gas
(810), whereby the first cooling chamber (600) is configured and
arranged to allow, in use, the first cooling gas (810) to enter the first
cooling chamber (600) through the at least one inlet (630) for the first
20 cooling gas (810), to pass out of the wire-facing outlet (651) for the first
cooling gas (810) away from the substrate (500), and to pass out of the
dispensing outlet (652) for the first cooling gas (810) towards the
substrate (500); and

wherein the dispensing channel (400) for the solder wire (200) is
25 comprised within the first cooling chamber (600).
2. Apparatus according to claim 1, wherein the first cooling chamber (600)
and the dispensing channel (400) for the solder wire (200) have similar

or the same dimensions in one or more regions inside the dispensing body (300).

3. Apparatus according to claim 1 or 2, wherein the dispensing outlet (652)
5 has similar or the same dimensions as the second end (470) of the dispensing channel (400) and/or the wire-facing outlet (651) has similar or the same dimensions as the first end (470) of the dispensing channel (400).
- 10 4. Apparatus according to any of the preceding claims, the apparatus (100) further comprising at least one auxiliary outlet for the first cooling gas (810), disposed outside the dispensing body (300), configured and arranged to allow, in use, at least a portion of the first cooling gas (810)
15 to pass from the first cooling chamber (600) towards the substrate (500).
5. Apparatus according to any preceding claim, wherein the first cooling gas (810) comprises nitrogen, carbon dioxide, helium, neon, argon, krypton, hydrogen, carbon monoxide or any combination thereof.
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6. Apparatus according to any preceding claim, wherein the first cooling gas (810) comprises nitrogen and 5% to 20% of hydrogen.
7. Apparatus according to any preceding claim, wherein the first cooling
25 gas (810) passing through the dispensing outlet (652) has a flow in the range of 0.1 to 5 liters per minute.
8. Apparatus according to any preceding claim, wherein the first cooling
30 gas (810) passing through the wire-facing outlet (651) has a flow in the range of 0.1 to 5 liters per minute.

9. Apparatus according to any preceding claim, wherein the at least one inlet (630) for the first cooling gas is disposed at an angle (950) of less than 90 degrees in a counter-clockwise direction to the longitudinal axis (900) of the dispensing body (300) if viewed in a longitudinal cross-section through the dispensing body (300) and the at least one inlet (630) for the first cooling gas (810).
10. Apparatus according to claim 9, wherein the at least one inlet (630) for the first cooling gas is disposed at an angle (950) of 30 degrees or more in a counter-clockwise direction to the longitudinal axis (900) of the dispensing body (300) if viewed in a longitudinal cross-section through the dispensing body (300) and the at least one inlet (630) for the first cooling gas (810).
11. Apparatus according to any preceding claims, wherein, in use, an average temperature of the first cooling gas (810) in at least a portion of the first cooling chamber (600) is predetermined and/or controlled to be 50 degrees Celsius or more below an average melting point of the solder wire (200).
12. Apparatus according to any of the preceding claims, the apparatus (100) further comprising a second cooling chamber (700), configured and arranged to cool a region of the dispensing body (300) with a second cooling gas (820), wherein the second cooling chamber (700) comprises at least one inlet (730) for the second cooling gas (820), and at least one outlet (750) for the second cooling gas (820), whereby the second cooling chamber (700) is configured and arranged to allow, in use, the second cooling gas (820) to enter the second cooling chamber (700) through the at least one inlet (730) for the second cooling gas (820), and to pass out of the at least one outlet (750) for the second cooling gas (820).

13. Apparatus according to claim 12, the apparatus (100) further comprising at least one auxiliary outlet for the second cooling gas (820), disposed outside the dispensing body (300), configured and arranged to allow, in use, the second cooling gas (820) to pass from the second cooling chamber (700) towards the substrate (500).
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14. Apparatus according to claim 12 or 13, wherein the second cooling gas (820) comprises nitrogen, carbon dioxide, helium, neon, argon, krypton, hydrogen, carbon monoxide, oxygen, air or any combination thereof.
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15. Apparatus according to any one of claim 12 or 13, wherein the second cooling gas (820) and the first cooling gas (810) are the same.