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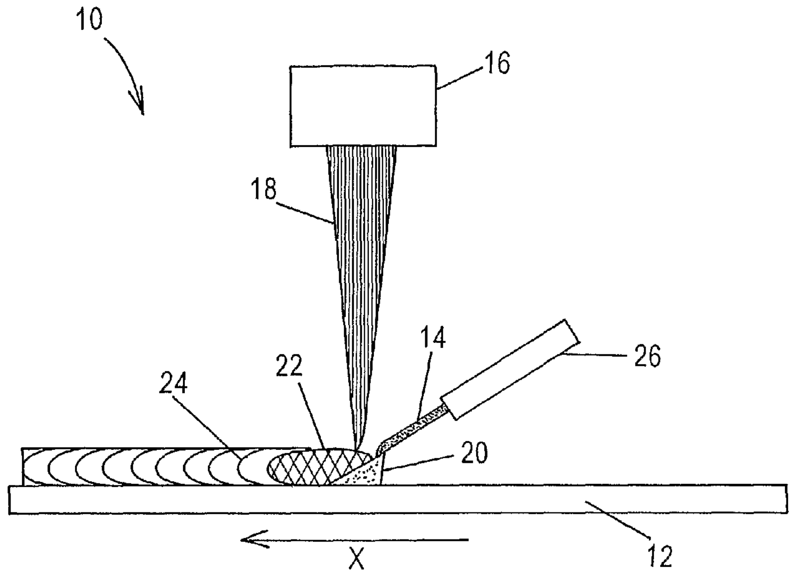
(54) **Title:** DIRECT METAL DEPOSITION USING LASER RADIATION AND ELECTRIC ARC



(57) **Abstract:** A direct metal deposition process using a laser/arc hybrid process to manufacture complex three-dimensional shapes comprising the steps of providing a substrate and depositing a first molten metal layer on the substrate from a metal feedstock using laser radiation and an electric arc is disclosed. The electric arc can be provided by gas metal arc welding using the metal feedstock as an electrode. The use of laser radiation in combination with gas metal arc welding stabilizes the arc and provides higher processing rates.

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DIRECT METAL DEPOSITION USING LASER RADIATION AND ELECTRIC ARC

CROSS-REFERENCE TO PROVISIONAL APPLICATION

[0001] This application claims priority from U.S. Provisional Patent Application No. 60/687,448 filed June 6, 2005, the entire disclosure of which is incorporated herein by reference.

GOVERNMENT RIGHTS STATEMENT

[0002] This invention was made with Government support under Agreement No. DAAD 19-02-9-0003, awarded by the Army Research Laboratory. The Government has certain rights in the invention.

TECHNICAL FIELD OF THE INVENTION

[0003] This invention relates to the application of a hybrid laser/arc process to Direct Metal Deposition for the purposes of making complex, three-dimensional shapes directly from metal powder or wire.

BACKGROUND OF THE INVENTION

[0004] The use of direct metal deposition (DMD) has been examined as a method to reduce manufacturing costs of complex, three-dimensional parts and parts made from expensive starting materials. The goal is to achieve near net shapes in high-cost materials thereby reducing the amount of waste material and time generated during machining. DMD has great potential for aerospace applications where the volume of parts is low, and the added value to the parts is high.

[0005] A DMD process has been developed that permits high deposition rates for complex shapes using a high-power (18 kW) CO_2 laser and powdered metal. The process is accomplished in a chamber under and argon and moisture atmosphere.

[0006] While the laser DMD process produces acceptable product, the operational cost for the CO_2 laser limits the applications based on the economics of the process. Because laser power is a low-efficiency means of melting the powder, the operational cost is high. More efficient methods of melting metal would include the use of arc or electron beam techniques.

Each of these processes has issues with implementing into the DMD process. As an example, gas metal arc techniques, similar to gas metal arc welding (GMAW), can be used to deposit metal materials but only produce acceptable depositions at slow speed/high heat input conditions.

[0007] The difference between DMD and welding, is that welding joins two substrates, while DMD builds up metal layers on a substrate. For example in GMAW, metal fills the joint between two substrates to join them together. Whereas, in a DMD process using a GMAW power supply and torch, metal is deposited on a substrate to build a three-dimensional structure on the substrate, not to join two substrates together.

[0008] Titanium's high specific strength and modulus, excellent corrosion resistance, high-temperature performance, and biocompatibility make it attractive to many different industries (aerospace, defense, petrochemical, medical). However, the reactive nature of Ti and its molten characteristics make it very difficult to form DMD products. Gas metal arc techniques have several disadvantages that severely limit their application to depositing Ti. These drawbacks include instabilities in metal transfer, excessive spatter, poor control of the deposited layer shape, and high heat input that causes distortion of thin sections during deposition. Also, an increase in productivity is not possible because of wandering of the cathode spot that occurs during deposition.

[0009] The combination of GMAW or gas tungsten arc welding (GTAW) and laser beam welding (LBW), called hybrid welding, has been extensively investigated. However, the combination of gas metal arc and laser beam DMD techniques have not been previously suggested.

SUMMARY OF THE INVENTION

[0010] There exists a need in this art for an economical method of performing direct metal deposition. There further exists a need in this art for a method of increasing throughput and yield of direct metal deposition formed products. A need further exists in this art for a direct metal deposition formed distortion-free products with smooth, well-defined deposition boundaries. In addition, a need exists in this art for a hybrid laser/gas metal arc direct metal deposition technique that minimizes spatter and provides a stabilized arc.

[0011] These and other needs are met by embodiments of the present invention, which provide a direct metal deposition process using a laser/arc hybrid process to manufacture complex, three-dimensional shapes comprising the steps of providing a substrate and depositing a first molten metal layer on the substrate from a metal feedstock using laser radiation and an electric arc.

[0012] These and other needs are further met by embodiments of the present invention, which provide a direct metal deposition process comprising the steps of providing a substrate and depositing a metal from a metal feedstock onto the substrate. An electric arc is generated between the metal feedstock and the substrate and the arc is exposed to laser radiation to form a molten metal pool on the substrate. The molten metal pool is cooled to form a first solid metal layer on the substrate.

[0013] These and other needs are further met by embodiments of the present invention, which provide a direct metal deposition process comprising the steps of providing a substrate and depositing a metal from a metal feedstock on a surface of the substrate. An electric arc is generated between the metal feedstock and the substrate as the arc is simultaneously exposed to laser radiation to form molten metal on the surface of the substrate. A gas is flowed over the metal while the electric arc is generated and the arc is exposed to the laser radiation. The metal is continuously fed to the surface of the substrate and the substrate is moved in relation to a source of the laser radiation and a source of the electric arc while the electric arc is generated and the arc is exposed to the laser radiation. The deposited metal is cooled to form a solid metal layer fixedly attached to the substrate.

[0014] This invention addresses the needs for an improved, economical method of performing direct metal deposition. This invention further addresses the need for a method of increasing throughput and yield of distortion-free direct metal deposition formed parts with smooth, well-defined deposition boundaries. In addition, this invention addresses the need for a hybrid laser/gas metal arc direct metal deposition technique that minimizes spatter and provides a stabilized arc.

[0015] The foregoing and other features, aspects, and advantages of the present invention will become apparent in the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 illustrates a hybrid laser/gas metal arc direct metal deposition according to an embodiment of the present invention.

[0017] FIG. 2 illustrates a hybrid laser/gas metal arc direct metal deposition with multiple arcs according to an embodiment of the present invention.

[0018] FIG. 3 illustrates a hybrid laser/gas metal arc direct metal deposition with multiple lasers according to an embodiment of the present invention.

[0019] FIG. 4 illustrates a hybrid laser/gas metal arc direct metal deposition with multiple feedstocks according to an embodiment of the present invention.

[0020] FIG. 5 illustrates a an embodiment of the present invention wherein multiple layers are deposited.

[0021] FIG. 6 illustrates a deposited structure formed by an omni-directional deposition process.

[0022] FIG. 7 is a cross-sectional view of a deposited metal on a substrate formed by the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0023] In certain embodiments of the present invention, the process uses a laser, a GMAW welder and a multi-axis, computer numerically controlled (CNC) positioning system to create three dimensional shapes directly in metal. Conventional laser DMD processes use a high energy density laser beam and a CNC-controlled positioning system to fuse metal powder or metal wire into complex three-dimensional shapes. The process of the present invention adds an electric arc to the process. The arc is coincident with the laser beam and is used in conjunction with the laser to melt the feedstock material and locally melt the substrate or previously deposited material to which the feedstock is being added. In certain embodiments of the present invention, an electrode is used to generate the arc between the metal feedstock and the substrate. In certain embodiments of the present invention, metal feedstock, such as wire, is used as a consumable electrode.

[0024] In certain embodiments of the present invention, an arc is established between a tungsten electrode and the substrate and the heat of the arc along with the laser radiation is used to melt incoming feedstock and a portion of the substrate. In such as a gas tungsten arc process, a non-consumable tungsten electrode is used in place of a consumable electrode. In certain embodiments of the present invention, a plasma arc process can be used with laser radiation to melt incoming feedstock.

[0025] An embodiment **10** of a hybrid laser/gas metal arc DMD process according to the present invention is schematically illustrated in Fig. **1**. A layer of metal **24** is deposited on a substrate **12**. A metal wire feedstock/GMAW electrode **14** supplies the metal to the substrate **12**. An electric arc **20** is generated between the metal wire feedstock/GMAW electrode **14** and the substrate **12** Laser radiation **18** is directed from a laser radiation source **16** to the electric arc **20.** A molten pool of metal **22** is formed by the laser radiation **18** and the electric arc **20**. The metal feedstock **14** is transferred across the arc **20** into the molten metal pool **22**. The metal wire feedstock/GMAW electrode **14** is supported by a wire guide **26**, which can also function as a gas nozzle for flowing gas across the molten metal **22,** in addition to supporting the wire **14**. During the deposition process the substrate is translated in the **X** direction relative to the source of laser radiation **16** and the arc **20**.

[0026] In certain embodiments of the present invention the metal is exposed to laser radiation simultaneously with the generation of the arc. In certain embodiments of the present invention, metal is continuously fed to the substrate during a period of time that the arc is generated and the arc is exposed to laser radiation. In certain embodiments of the present invention, the substrate is moved in relation to a source of the laser radiation and a source of the arc during the period of time that the arc is generated and the arc is exposed to laser radiation.

[0027] The DMD process of the present invention differs from the hybrid welding process in that it deposits metal to build up three-dimensional shapes on a substrate directly from feedstock material, rather than joining two substrates together. Whereas in the hybrid welding process, metal is deposited in the joint between two metal substrates, to join the metal substrates together. DMD processes of the present invention produce complex, three dimensional shapes, unlike cladding processes, which form a substantially flat layer on a substrate.

[0028] According to certain embodiments of the present invention, multiple laser radiation sources and arcs can be used. FIG. **2** illustrates an embodiment of the present invention **30** that uses a plurality of metal wire feedstock/GMAW electrodes **14.** An embodiment of the present invention **40** using multiple laser radiation sources 16 is illustrated in FIG. **3**. In certain embodiments of the present invention **50**, multiple feedstocks can be employed, as shown in

FIG. **4**. The additional feedstock **52** can either be an additional metal wire or a metal powder. The additional metal feedstock **52** can be supported by a wire guide **54** or a powder dispenser **54** depending on whether the metal feedstock **52** is a wire or powder. In certain embodiments of the present invention, multiple wire feeds **52** using wires of differing compositions can be used to create an alloy different from the substrate **12** or any of the other feedstock **14** materials.

[0029] The process of the present invention is applicable to a wide range of metals including titanium, titanium alloys, iron, iron alloys, nickel, nickel alloys, rhenium, rhenium alloys, tantalum, tantalum alloys, cobalt, cobalt alloys, aluminum, aluminum alloys, and mixtures thereof. In certain embodiments of the present invention, the metals are Ti alloys, such as TiAlV alloys; or iron alloys, such as steel and stainless steel.

[0030] In certain embodiments of the present invention, a titanium alloy deposit, such as Ti-6Al-4V, can be formed in the melt pool by using a Ti wire feedstock, and both Al and V wire or powder feedstocks. The powders, if used, can be mixed prior to deposition or in the melt pool.

[0031] Generally, the metal feedstock is the same type of metal as the substrate. However, in certain embodiments of the present invention, a different metal or alloy than the substrate can be used as the metal feedstock. In addition, in other embodiments of the present invention, different layers in a multilayer deposition can be formed from different metals or different alloys.

[0032] The diameter of the metal wire feedstock, according to certain embodiments of the present invention, can range from about 0.030 inches to about 0.094 inches. In certain embodiments of the present invention, a metal wire feedstock with a diameter of about 0.063 inches is used.

[0033] Metal powder can be used in conjunction with the feedstock wire as a supplemental material, as illustrated in FIG. **4**, in certain embodiments of the present invention. The powder can be of the same composition as the substrate, the wire, or may be a different composition than either the substrate and/or the wire. In certain embodiments of the present invention, the powder can contain non-metallic additives, such as inoculants to reduce grain size; silica; ceramics, such as alumina, for wear-resistance applications, and ceramics conventionally used in forming blade tips; or anything else that enhances a property of the alloy. In addition, to ceramic inoculants, high temperature metals can also be used as inoculants. In certain embodiments of the present invention, the particle size of the metal powder feedstock ranges from - 35 mesh sieve to + 325 mesh sieve.

[0034] The process of the present invention can be performed in vacuum, in an inert-gas chamber or in atmosphere with localized gas shielding. The gases in the inert-gas chamber or in the localized shielding can be of high-purity to minimize contamination or can contain additives which react with or are absorbed by the molten pool in order to create a desired effect. In certain embodiments of the present invention, oxygen is added to the gas when depositing titanium alloys, resulting in an alloy with a higher oxygen content than there would have been without the oxygen additive to the gas. The effect of the higher oxygen level on the material is an alloy with increased tensile strength. In certain embodiments of the present invention, nitrogen, carbon dioxide, or carbon monoxide can be added to the shielding gas. Like oxygen, the addition of nitrogen, carbon dioxide, and carbon monoxide raise the interstitial content of the deposited titanium and increase its strength.

[0035] The parameters of the process can be varied such that the material fuses to a required density. For most aerospace applications, the requirement is full density in metals. Since the geometry of the features of a part vary, the energy requirements to ensure full density will change accordingly. For example, thick sections on a part require a higher heat input than thinner sections on the same part. Processing parameters can be varied, in certain embodiments of the present invention, in order to maintain geometry requirements, such as a level build or a change in cross section. For example, a thin wall on a part requires less material per unit length than a thicker wall on the same part.

[0036] The present invention can be performed using a GMAW power supply coupled with a laser. In certain embodiments, either or both of the arc and the laser radiation may be continuous or pulsed. In certain embodiments of the present invention, the laser can be a Nd:YAG, CO_2, or a Yb-doped fiber laser.

[0037] In certain embodiments of the present invention, the substrate is positioned on a moving platform, such as a 4-axis CNC motion-controlled table. In certain embodiments of the present invention, the laser radiation is oriented substantially normal to the substrate surface and the GMAW electrode is oriented at an acute angle to the substrate surface, as shown in Figure 1. In certain embodiments of the present invention, the GMAW electrode is oriented at an angle of about 50° to about 90° to the substrate. In certain embodiments of the present invention, the wire guard includes a gas nozzle to supply a shielding gas. In certain embodiments of the present invention, the shielding gas is an inert gas, such as argon or helium.

[0038] In certain embodiments of the present invention, lasers with a power ranging from about 400 W to about 20 kW can be used to generate the laser radiation. In certain embodiments of the invention the laser spot size ranges from a diameter of about 0.01 inches to about 0.3 inches. There is no known limit on the laser power and laser spot size. As the laser power is increased the laser spot size increases and the rate of metal deposition increases. In certain embodiments of the present invention, about 12 pounds of metal can be deposited per hour. In certain embodiments of the present invention, the amount of metal deposited ranges up to 20 pounds metal per hour. In certain embodiments of the present invention, a greater amount of laser power can be provided for arc stabilization as travel speed increases at the same spot size.

[0039] Initiation of the arc occurs when the wire momentarily touches or strikes a metal surface. During arc initiation metal can spatter. Spattering can be reduced by optimizing the arc initiation conditions of the laser/gas metal arc deposition process. To decrease spatter the laser power can be reduced and the travel speed increased. In certain embodiments of the present invention, the GMAW electrode can be oriented substantially vertical to the substrate and the laser radiation can be oriented at an acute angle to the substrate.

[0040] Processes according to the present invention have a wide range of applications. In aerospace applications, parts formed according to the present invention can be used as bulkheads, pylon panels, pylon ribs, splice plates, wing folds, vertical tail spars, and frames.

[0041] In certain embodiments of the present invention, substrates up to 10 feet in length and 3 feet wide can be deposited with metal up to 6 inches or greater in depth on both sides of the substrate. Allowing the formation of parts with a thickness of over 12 inches. There is no known limit on the width, length, and thickness of the deposited layer, other than those dictated by the dimensions and capacity of the deposition chamber. The substrate is usually a part of the finished part, but in certain embodiments of the present invention, the substrate can be removed from the deposited metal structure, such as by machining, to produce a self-supported direct metal deposited part.

[0042] Parts formed according to the present invention can be formed on a flat substrate. Alternatively, the substrates can be castings or forgings, with complex features deposited thereon using the process of the present invention. The present invention, thus, allows the formation of complex part geometries that cannot be cast or forged.

[0043] The deposited metal layer, according to the present invention, is fixedly adhered to the substrate by forming a metallurgical bond to the substrate surface. In certain embodiments of the present invention, the inventive process, the melt depth of the deposited metal layer ranges from less than about 0.050 inches to about 0.25 inches.

[0044] The thickness of a single deposited layer, according to certain embodiments of the present invention, can range from about 0.050 inches to about 0.25 inches. In certain embodiments of the present invention, each deposited layer ranges from about 0.1 inches to about 0.2 inches thickness. Thus, multiple deposition passes are required to build up the deposited metal layer in applications requiring thicker layers. An embodiment of the present invention **70** illustrating the formation of multiple deposited layers is shown in FIG. **5**. Subsequent to the deposition of the first metal layer **72**, the substrate **12** is lowered in the Z direction, relative to the arc and laser sources, and a second metal layer **74** is deposited in the same manner as described herein for forming single layers. To ensure the registration of subsequently deposited layers **74**, a CNC positioning system (not shown) is used to move the substrate as required.

[0045] Direct metal deposition processes according to the present invention can be used to fabricate complex shapes. For example a "U" shaped element **60** as illustrated in FIG. **6** (or circular element (not shown)), can be formed without stopping or resetting the position or orientation of the laser radiation source and metal feedstock/metal arc electrode. As shown in FIG. **6**, the "U" shaped element includes opposed legs **62, 64** connected by transverse leg **66**. Legs of the "U" shaped element are formed by omni-directional deposition, as illustrated by arrows **67, 68, 69**.

[0046] A cross-sectional view **80** of a deposited metal **84** on a substrate **82** formed by the present invention is illustrated in FIG. **7**. The metal layer **84** is fixedly attached to the surface **88** of the substrate **82**, as evidenced by the melt depth **86** into the substrate **82**.

[0047] In order to eliminate residual stresses and distortion and to optimize mechanical and metallurgical properties, parts formed according to the present invention can be subsequently heat treated, as in prior art direct metal deposition processes.

[0048] The embodiments illustrated in the instant disclosure are for illustrative purposes. They should not be construed to limit the scope of the claims. As is clear to one of ordinary skill in this art, the instant disclosure encompasses a wide variety of embodiments not specifically illustrated herein.

WHAT IS CLAIMED IS:

1. A direct metal deposition process using a laser/arc hybrid process to manufacture complex, three-dimensional shapes comprising the steps of:

providing a substrate; and

depositing a first molten metal layer on the substrate from a metal feedstock using laser radiation and an electric arc.

2. The direct metal deposition process according to claim 1, wherein the metal feedstock comprises a metal wire.

3. The direct metal deposition process according to claim 2, wherein the metal feedstock further comprises a metal powder.

4. The direct metal deposition process according to claim 1, further comprising cooling the molten metal layer to form a solid metal layer.

5. The direct metal deposition process according to claim 4, further comprising depositing one or more additional metal layers overlying the solid metal layer.

6. The direct metal deposition process according to claim 1, further comprising flowing a gas over the metal layer.

7. The direct metal deposition process according to claim 6, wherein the gas is an inert gas.

8. The direct metal deposition process according to claim 6, wherein the gas comprises oxygen, nitrogen, carbon monoxide, or carbon dioxide.

9. The direct metal deposition process according to claim 1, wherein the metal feedstock is selected from the group consisting of titanium, titanium alloys, iron, iron alloys, nickel, nickel alloys, rhenium, rhenium alloys, tantalum, tantalum alloys, cobalt, cobalt alloys, aluminum, aluminum alloys, and mixtures thereof.

10. The direct metal deposition process according to claim 1, wherein the metal feedstock comprises a mixture of a metal and a ceramic.

11. The direct metal deposition process according to claim 1, wherein the substrate comprises a metal.

12. The direct metal deposition process according to claim 11, wherein the substrate and the metal feedstock comprise the same metal.

13. A direct metal deposition process comprising the steps of:

(a) providing a substrate;

(b) depositing a metal from a metal feedstock onto the substrate;

(c) generating an electric arc between the metal feedstock and the substrate and exposing the arc to laser radiation to form a molten metal pool on the substrate;

(d) cooling the molten metal pool to form a first solid metal layer on the substrate.

14. The direct metal deposition process according to claim 13, further comprising the steps of:

(e) depositing additional metal onto the first metal layer; and

repeating steps (c), (d), and optionally (e) to form one or more additional metal layers overlying the first metal layer.

15. The direct metal deposition process according to claim 13, wherein the metal feedstock comprises a metal wire.

16. The direct metal deposition process according to claim 15, wherein the metal feedstock further comprises a metal powder.

17. The direct metal deposition process according to claim 15, wherein the metal wire is a consumable electrode.

18. The direct metal deposition process according to claim 13, wherein the arc is exposed to laser radiation simultaneously with the generation of the arc.

19. The direct metal deposition process according to claim 13, wherein the metal is continuously fed to the substrate during a period of time that the arc is generated and the arc is exposed to laser radiation.

20. The direct metal deposition process according to claim 19, further comprising moving the substrate in relation to a source of the laser radiation and a source of the arc during the period of time that the arc is generated and the arc is exposed to laser radiation.

21. The direct metal deposition process according to claim 13, further comprising flowing a gas over the molten metal.

22. The direct metal deposition process according to claim 21, wherein the gas comprises an inert gas.

23. The direct metal deposition process according to claim 21, wherein the gas comprises oxygen, nitrogen, carbon monoxide, or carbon dioxide.

24. The direct metal deposition process according to claim 13, wherein the laser radiation is oriented substantially normal to the substrate.

25. The direct metal deposition process according to claim 24, wherein the arc is oriented at an acute angle to the substrate.

26. The direct metal deposition process according to claim 13, wherein the laser radiation is pulsed laser radiation.

27. The direct metal deposition process according to claim 13, wherein the arc is a pulsed arc.

28. The direct metal deposition process according to claim 13, wherein the metal feedstock comprises a plurality of feedstocks.

29. The direct metal deposition process according to claim 13, wherein the arc is exposed to laser radiation from a plurality of laser radiation sources.

30. The direct metal deposition process according to claim 13, wherein the arc is generated between a plurality of electrodes and the substrate.

31. A direct metal deposition process comprising the steps of:

providing a substrate;

depositing a metal from a metal feedstock on a surface of the substrate;

simultaneously generating an electric arc between the metal feedstock and the substrate, and exposing the arc to laser radiation to form molten metal on the surface of the substrate;

flowing a gas over the metal while the electric arc is generated and the arc is exposed to the laser radiation;

continuously feeding the metal to the surface of the substrate and moving the substrate in relation to a source of the laser radiation and a source of the electric arc while the electric arc is generated and the arc is exposed to the laser radiation; and

cooling the deposited metal to form a solid metal layer fixedly attached to the substrate.

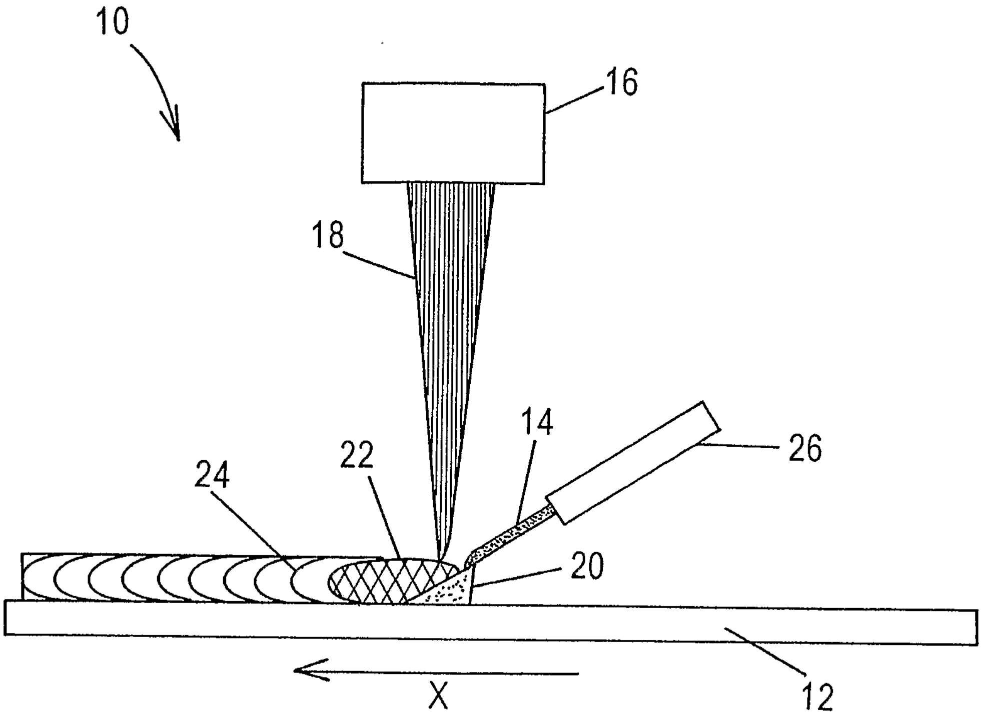

FIG. 1

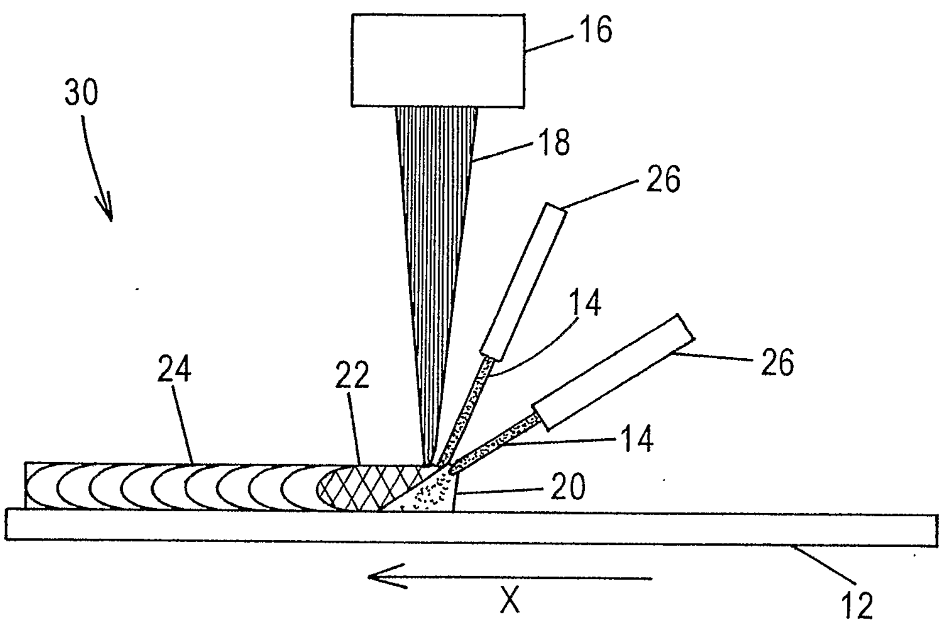

FIG. 2

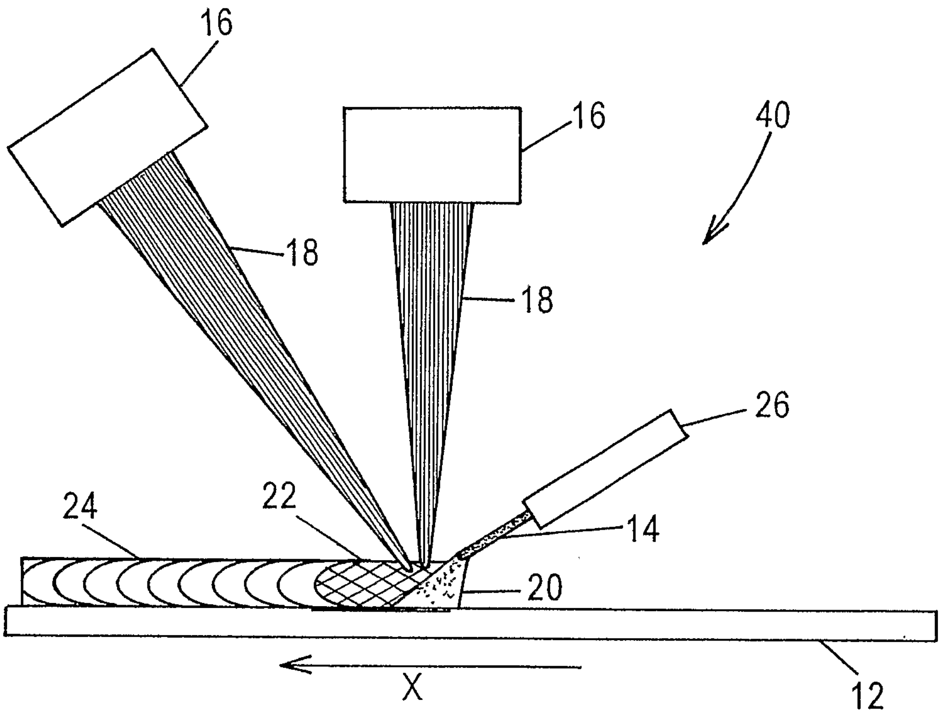

FIG. 3

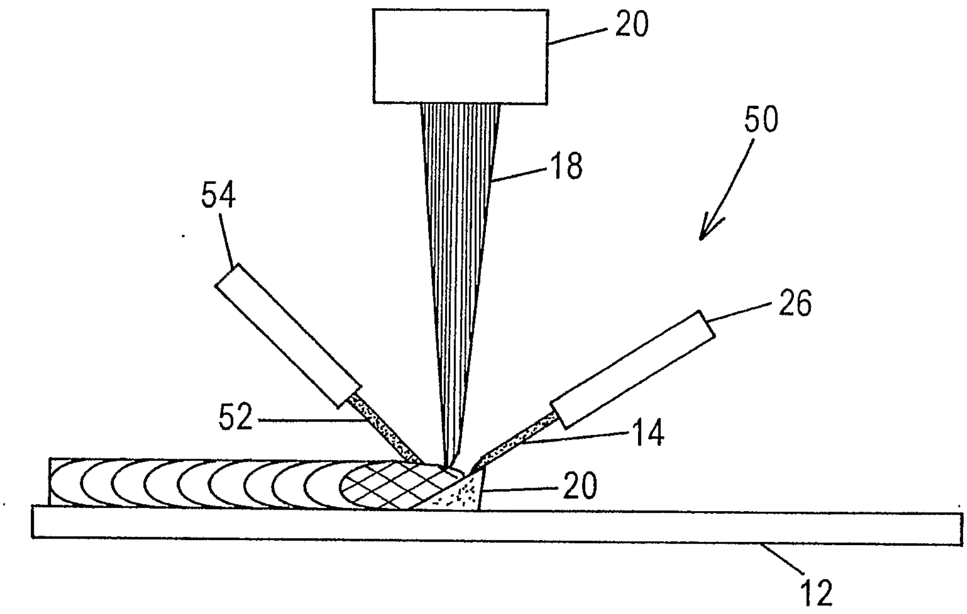

FIG. 4

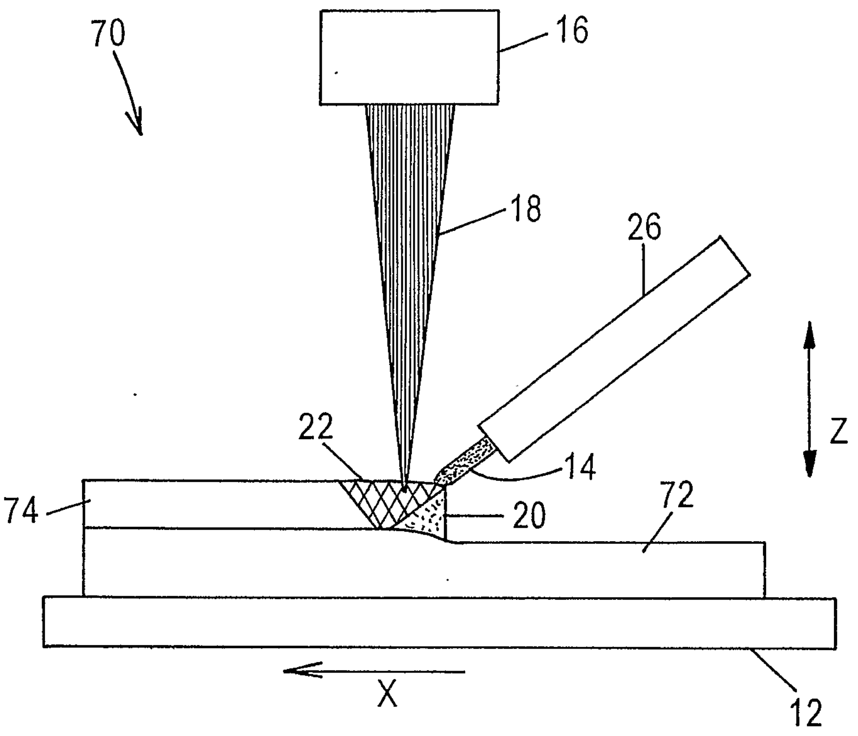

FIG. 5

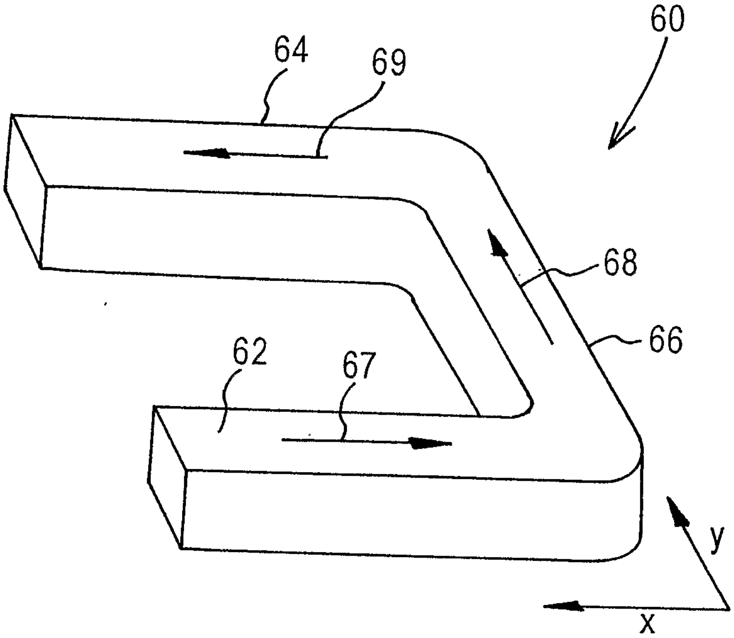

FIG. 6

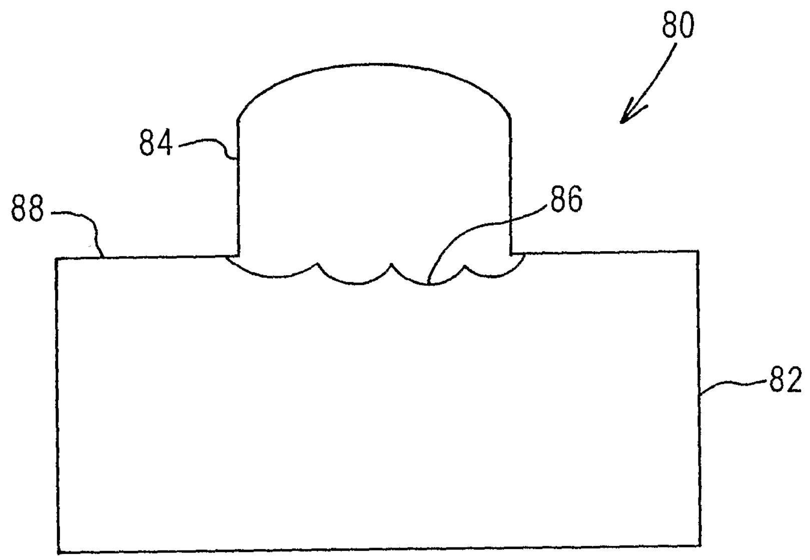

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/021635

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C4/12 B23K26/14 B23K9/04 B23K26/34

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)
C23C B23K

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 practical, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 03/102260 A2 (PRECO LASER SYSTEMS LLC [US]; DE KOCK JOEL A [US]; DOEHRMANN ANTHONY [) 11 December 2003 (2003-12-11)	1-4,6-9, 11-13, 15-25, 27,28,31
Y	page 6, line 12 - page 14, line 23; figures 1-4 page 11, line 16 - page 12, line 5 page 15, lines 6-15; figure 6 page 17, line 26 - page 18, line 1	5,14

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2006	19/10/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hoyer, Wolfgang

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/021635

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Y	WO 97/05984 A (WESTINGHOUSE ELECTRIC CORP [US]) 20 February 1997 (1997-02-20) page 5, lines 15-29; figures 1,2	5,14

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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