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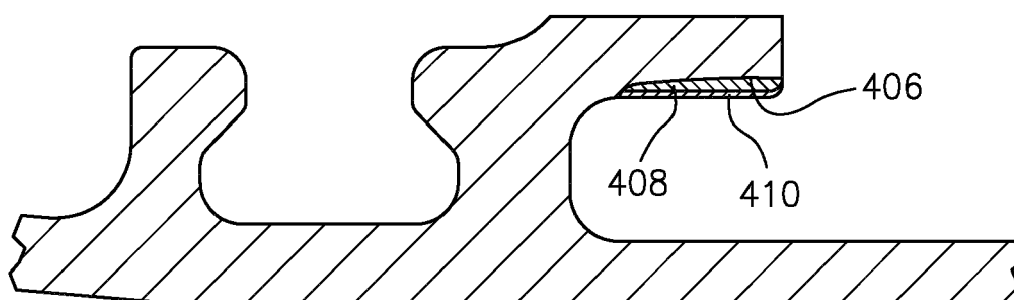
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(54) **METHOD OF REPAIRING A NON-LINE OF SIGHT FEATURE VIA A MULTI-LAYER COATING**

(57) Aspects of the disclosure are directed to a method of repairing a non-line of sight feature on a surface (402), the method comprising machining a worn irregular non-line of sight surface (402) to provide a substantially planar repair surface (406), depositing a nickel plate base

layer (408) having a base layer thickness on the substantially planar repair surface (406), and depositing a protective layer (410) having a protective layer (410) thickness on the nickel plate base layer (408).



**FIG. 4D**

## Description

### BACKGROUND OF THE INVENTION

#### 1. Technical Field

**[0001]** The present disclosure relates to a method of using a multi-layer coating for dimensional restoration of a non-line of sight surface, more particularly to repairing a non-line of sight worn surface of a gas turbine engine component that is subjected to high operating temperatures.

#### 2. Background Information

**[0002]** Wear due to abrasion, fretting, galling, et cetera, often causes material loss beyond part blueprint dimensional limits. Besides wear, other mechanisms incurred during typical engine operation are also known to cause dimensional changes in parts that may lead to unserviceable conditions, such as for example, but not limited to: creep, oxidation, corrosion, etc. Many dimensional restoration processes exist, such as for example, plasma spray processing, welding, plating, etc. However, processes such as plasma spray processing are dependent on adequate "line-of-sight" in order to achieve a sufficient quality layer to restore part function by dimensional restoration. Line-of-sight is critical as it sets gun-to-part angles, allows accessibility by the equipment, et cetera. Welding also requires adequate line-of-sight to some degree to allow the welding torch and filler metal to access the worn features. However, welding may cause significant distortion of the part and/or a reduction of parent material properties to the point of being unusable (e.g., scrapped). Plating does not require line-of-sight, however, the most common electrolytic platings, such as nickel, suffer from softening and oxidation at temperatures above approximately 1000 °F (537.8 °C). However, temperatures up to approximately 1300 °F (704.4 °C) are expected for certain gas turbine engine components that have one or more non-line of sight surfaces requiring dimensional restoration. Thus, these high operating temperature requirements prevent conventional electrolytic nickel plating from being utilized to repair worn non-line of the sight surfaces. It is recognized that wear may not be the only cause for a part requiring dimensional restoration; other causes may include part growth due to creep mechanisms, part distortion, and/or excessive machining.

**[0003]** FIG. 1 is a simplified illustration showing a surface that requires dimensional restoration of a non-line of sight surface. As an example, the surface may be a mating surface associated with a high pressure compressor rear hub 100 and a high pressure turbine 1<sup>st</sup> stage heat shield 102 of a gas turbine engine. Surfaces of these two components 100, 102 fit with tight tolerance requirements. FIG. 2 is an exploded view of a mating surface 104 on the high pressure compressor rear hub 100 that

contacts a face to face surface on the high pressure turbine 1<sup>st</sup> stage heat shield 102. Use of the engine causes the mating surface 104 of the high pressure compressor rear hub 100 to wear, as shown in FIG. 3. Because of the tight confines in area and the high operating temperature the non-line of sight surface 104 is exposed to, conventional techniques used to repair line of sight features cannot be used to repair the non-line of sight surface 104.

**[0004]** There is a need in the art for an improved process for dimensionally restoring a non-line of sight surface that is subject to high operating temperatures (i.e., greater than 1000 °F or 538 °C).

### 15 SUMMARY OF THE DISCLOSURE

**[0005]** The following presents a simplified summary in order to provide a basic understanding of some aspects of the disclosure. The summary is not an extensive overview of the disclosure. It is neither intended to identify key or critical elements of the disclosure nor to delineate the scope of the disclosure. The following summary merely presents some concepts of the disclosure in a simplified form as a prelude to the description below.

**[0006]** Aspects of the disclosure are directed to a method of repairing a non-line of sight feature on a surface, the method comprising machining a worn irregular non-line of sight surface to provide a substantially planar repair surface, depositing a nickel plate base layer having a base layer thickness on the substantially planar repair surface, and depositing a protective layer having a protective layer thickness on the nickel plate base layer.

**[0007]** Depositing the protective layer may comprise depositing using vapor deposition.

**[0008]** Depositing using vapor deposition may comprise one of physical vapor deposition (PVD), electron-beam physical vapor deposition (EBPVD), or chemical vapor deposition (CVD).

**[0009]** Depositing the protective layer may comprise depositing MCrAlY.

**[0010]** Depositing the protective layer may comprise depositing a cobalt alloy.

**[0011]** Depositing the protective layer may comprise depositing the protective layer using at least one of a powder pack process, or locally applying at least one of paint, paste, slurry or thermal spray.

**[0012]** The protective layer may comprise an aluminate.

**[0013]** The protective layer may comprise a chromide.

**[0014]** The protective layer may have thickness of about 0.001 to 0.002 inches (0.0254 to 0.0508 mm) and the base layer thickness may be about 0.0005 to 0.002 inches (0.0127 to 0.0508 mm).

**[0015]** Depositing the nickel plate base layer may comprise depositing an electrolytic nickel plate base layer.

**[0016]** Depositing the nickel plate base layer may comprise depositing an electroless nickel plate base layer

**[0017]** Aspects of the disclosure are also directed to a

method of repairing a non-line of sight feature on a surface of a gas turbine engine component, the method comprising machining a worn irregular non-line of sight surface of the gas turbine engine component to provide a substantially planar repair surface, depositing a nickel plate base layer having a base layer thickness on the substantially planar repair surface, and depositing a protective layer having a protective layer thickness on the nickel plate base layer.

**[0018]** Depositing the protective layer may comprise one of physical vapor deposition (PVD), electron-beam physical vapor deposition (EBPVD), or chemical vapor deposition (CVD).

**[0019]** Depositing the protective layer may comprise depositing at least one of MCrAlY and cobalt alloy.

**[0020]** Depositing the protective layer may comprise applying at least one of a diffused aluminide and a diffused chromide.

**[0021]** Depositing the nickel plate base layer may comprise depositing an electrolytic nickel plate base layer.

**[0022]** Aspects of the disclosure are further directed to a method of repairing a feature on a surface, the method comprising machining a worn irregular sight surface to provide a substantially planar repair surface, depositing a nickel plate base layer having a base layer thickness on the substantially planar repair surface, and depositing a protective layer having a protective layer thickness on the nickel plate base layer.

**[0023]** The depositing using vapor deposition may comprise one of physical vapor deposition (PVD), electron-beam physical vapor deposition (EBPVD), or chemical vapor deposition (CVD).

**[0024]** The protective layer may comprise at least one of MCrAlY, cobalt alloy, diffused aluminide and diffused chromide.

**[0025]** Depositing the nickel plate base layer may comprise depositing an electrolytic nickel plate base layer.

#### BRIEF DESCRIPTION OF THE DRAWINGS

##### **[0026]**

FIG. 1 is a simplified illustration showing a prior art mating surface associated with a high pressure compressor rear hub and a high pressure turbine 1<sup>st</sup> stage heat shield of a gas turbine engine.

FIG. 2 is an exploded view of the mating surface formed by the high pressure compressor rear hub and a high pressure turbine 1<sup>st</sup> stage heat shield of FIG. 1.

FIG. 3 is a simplified illustration of a worn mating non-line of sight surface of the high pressure compressor rear hub that is difficult to repair using conventional line-of-sight repair techniques.

FIGs. 4A-4D illustrate the repair of a non-line of sight surface according to an exemplary method of the disclosure.

FIG. 5 is a flow-chart illustration of an embodiment

of a method of repairing worn non-line of sight features using multi-layer coating.

#### DETAILED DESCRIPTION

**[0027]** As set forth above, because of the tight confines adjacent to a surface to be repaired, conventional techniques associated with the repair of line of sight surfaces cannot be used to repair the non-line of sight worn surface illustrated in FIG. 3. "Non-line of sight feature(s)" or "non-line of sight surface(s)" are feature(s)/surface(s) of a part where typical dimensional restoration processes, such as welding and plasma spray processes, cannot be utilized due to geometrical constraints of the part and/or inadequate accessibility of the associated equipment involved. It is known that existing techniques for bouncing or reflecting thermal spray streams off nearby features are often employed to repair such surfaces, however, it is important to note that they require a higher degree of line-of-sight versus the proposed method.

**[0028]** Referring to FIG. 4A, a non-line of sight/limited line of sight surface 402 that is worn is machined or ground using a tool 404. The non-line of sight/limited line of sight surface 402 may be, for example, a surface on the high pressure compressor rear hub (e.g., see hub 100 in FIG. 1). The tool may be a cutting head or a grinding tool, for example, of a CNC machine. As shown in FIG. 4B, the worn surface 402 (FIG. 4A) is machined/ground to provide a substantially planar surface 406, which may then be cleaned to prepare for subsequent processing. As shown in FIG. 4C a nickel plate base layer 408 is then deposited onto the substantially planar surface 406. The base layer 408 provides dimensional restoration to bring the worn surface 402 (FIG. 4A) to an acceptable condition (e.g., thickness). The nickel plate base layer 408, which is a non-line of sight surface/limited line of sight surface can be deposited using an electroless or electrolytic nickel plating technique and has a base thickness of about 0.5-2 mils (0.0005 to 0.002 inches or 0.0127 to 0.0508 mm) and 3-20 mils (0.003 to 0.02 inches or 0.0762 to 0.508 mm), respectively. The nickel plate base layer 408 may be deposited for example using the methodology set forth in SAE's known process AMS 2424 for electrolytic nickel plating. It is contemplated that the base layer 408 may also be deposited using an electroless plating process (e.g., SAE AMS 2404). It is also contemplated that the base layer 408 may be a material other than nickel, such as for example copper plating.

**[0029]** However, such a nickel plate base layer is known to have poor oxidation and abrasion resistance, especially above 1000 deg. F (538 deg. C), which may lead to accelerated wear and possible spallation, liberating coating, et cetera.

**[0030]** Since the nickel plate base layer 408 may be exposed to nominal temperatures in excess of 1300 deg. F (704 deg. C) during operation of a gas turbine engine, the nickel plated base layer 408 would not provide the requisite life span. To protect the nickel plated base layer

408, a relatively thin protective layer may be applied. Referring to FIG. 4D, next a protective layer 410 is deposited on the nickel plate base layer 408. The protective layer 410 provides oxidation and/or abrasion resistance and/or otherwise modify the wear couple at the mating surfaces to protect the base layer 408 (e.g., from deterioration). The protective layer 410 may be deposited using vapor deposition.

**[0031]** The protective layer 410 may, for example, be diffused aluminide having a thickness of about 0.001 - 0.002 inches (0.0254 - 0.0508 mm). The protective layer 410 may be deposited using a powder pack process, vapor phase, or locally applied in the form of paint/paste/slurry/thermal spray. The protective layer 410 may also be deposited using vapor deposition processes, such as for example, physical vapor deposition (PVD) (e.g., CATARC® PVD), electron-beam physical vapor deposition (EBPVD), chemical vapor deposition (CVD), et cetera, to a thickness of about 0.0005-0.002 inches (0.0127 - 0.0508 mm). The protective layer 410 may also be a MCrAlY type coating deposited to a thickness of about 0.0005-0.002 inches (0.0127 - 0.0508 mm), including Stellite/cobalt coatings. The MCrAlY type protective coating may be deposited using vapor deposition. The sum of the nickel base layer thickness and the protective layer thickness may be equal to the original component thickness dimension in order provide the desired dimensional restoration.

**[0032]** FIG. 5 is a flow-chart illustration of an embodiment of a method of repairing worn non-line of sight features using a multi-layer coating. In step 500, a non-line of sight surface/limited line of sight surface (e.g., see surface 402 in FIG. 4A) is prepared for subsequent coating steps by machining/grinding the surface to provide a planar surface (e.g., see planar surface 406 in FIG. 4B). In step 502 a nickel plate base layer (e.g., see layer 408 in FIG. 4C) is deposited onto the planar surface. In step 504 a protective layer (e.g., see layer 410 in FIG. 4C) is deposited on the nickel plate base layer, using for example, vapor deposition. The vapor deposition process occurs in a deposition chamber under controlled conditions. It is contemplated of course the repair method may also be used to features/surfaces that have a line of sight.

**[0033]** To deposit the protective layer 410 on the non-line of sight/limited line of sight surface using vapor deposition, a skilled person will appreciate that the deposition process must ensure that the non-line of sight/limited line of sight surfaces to be coated are properly exposed to the vapor cloud in the deposition chamber. Examples of such techniques are disclosed in U.S. Patents 8,541,069 and 9,885,110, which are assigned to the assignee of the present invention.

**[0034]** Although the different non-limiting embodiments have specific illustrated components and/or steps, the embodiments are not limited to those particular combinations. It is possible to use some of the components or features from any of the non-limiting embodiments in combination with features or components from any of the

other non-limiting embodiments.

**[0035]** It should be understood that like reference numerals identify corresponding or similar elements throughout the several drawings. It should also be understood that although a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit herefrom.

**[0036]** The foregoing description is exemplary rather than defined by the features within. Various non-limiting embodiments are disclosed herein, however, one of ordinary skill in the art would recognize that various modifications and variations in light of the above teachings will fall within the scope of the appended claims. It is therefore to be understood that within the scope of the appended claims, the disclosure may be practiced other than as specifically described. For that reason the appended claims should be studied to determine true scope and content.

## Claims

1. A method of repairing a feature on a surface, the method comprising:
  - machining a worn irregular surface (402) to provide a substantially planar repair surface (406);
  - depositing an nickel plate base layer (408) having a base layer thickness on the substantially planar repair surface (406); and
  - depositing a protective layer (410) having a protective layer thickness on the nickel plate base layer (408).
2. The method of claim 1, wherein the feature is a non-line of sight feature, and the worn irregular surface (402) is a worn irregular non-line of sight surface (402).
3. The method of claim 1 or 2, wherein the surface is a surface of a gas turbine engine component.
4. The method of claim 1, 2 or 3, where the depositing the protective layer (410) comprises depositing using vapor deposition.
5. The method of any preceding claim, where the depositing the protective layer (410), e.g. using vapor deposition, comprises one of physical vapor deposition (PVD), electron-beam physical vapor deposition (EBPVD), or chemical vapor deposition (CVD).
6. The method of any preceding claim, where the depositing the protective layer (410) comprises depositing MCrAlY.
7. The method of any preceding claim, where the depositing the protective layer (410) comprises depos-

iting a cobalt alloy.

8. The method of claim 1, 2 or 3, where the depositing the protective layer (410) comprises depositing the protective layer (410) using at least one of a powder pack process, or locally applying at least one of paint, paste, slurry or thermal spray. 5
9. The method of claim 8, where protective layer (410) comprises an aluminide. 10
10. The method of claim 8 or 9, where protective layer (410) comprises a chromide.
11. The method of any preceding claim, where the protective layer (410) thickness is about 0.001 to 0.002 inches (0.0254 to 0.0508 mm) and the base layer thickness is about 0.0005 to 0.002 inches (0.0127 to 0.0508 mm). 15  
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12. The method of any preceding claim, where the depositing the nickel plate base layer (408) comprises depositing an electrolytic nickel plate base layer (408). 25
13. The method of any of claims 1-12, where the depositing the nickel plate base layer (408) comprises depositing an electroless nickel plate base layer (408).
14. The method of claim 1, 2 or 3, where the depositing the protective layer (410) comprises applying at least one of a diffused aluminide and a diffused chromide. 30
15. The method of any preceding claim, where the protective layer (410) comprises at least one of MCrAlY, cobalt alloy, diffused aluminide and diffused chromide. 35

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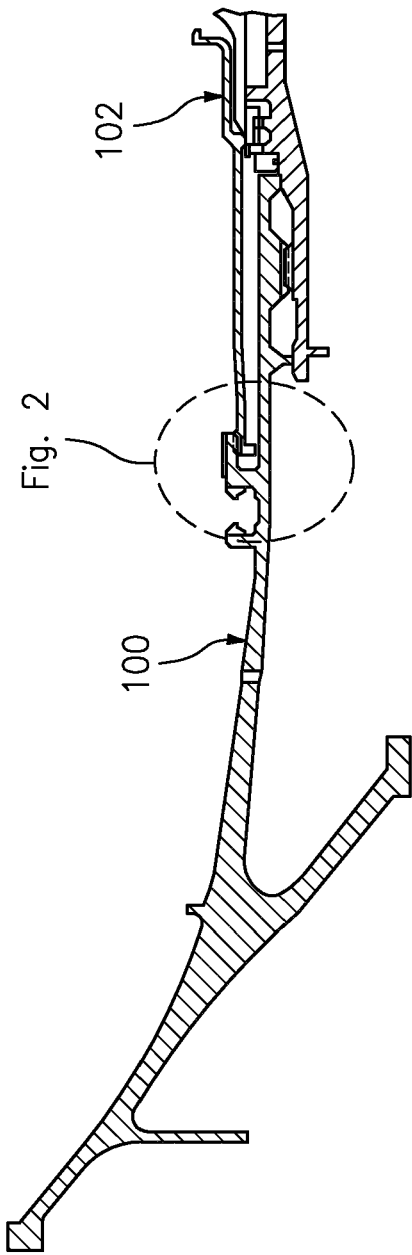


FIG. 1

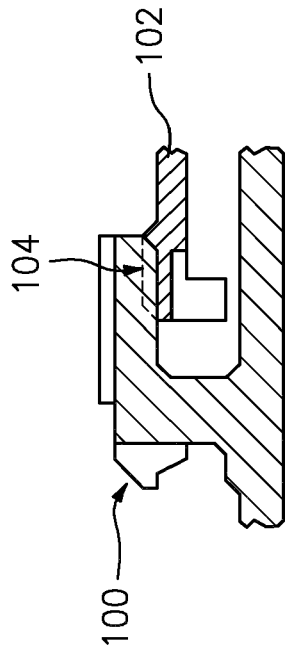


FIG. 2

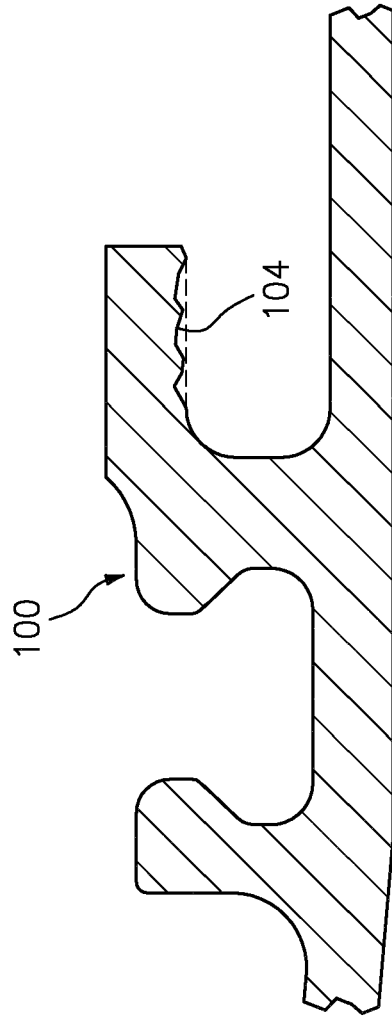
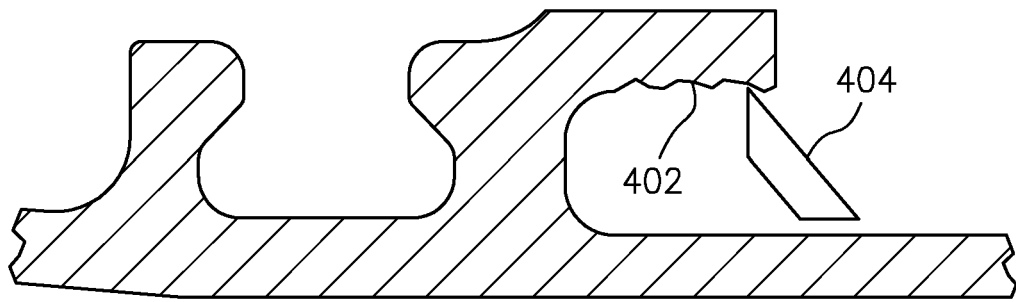
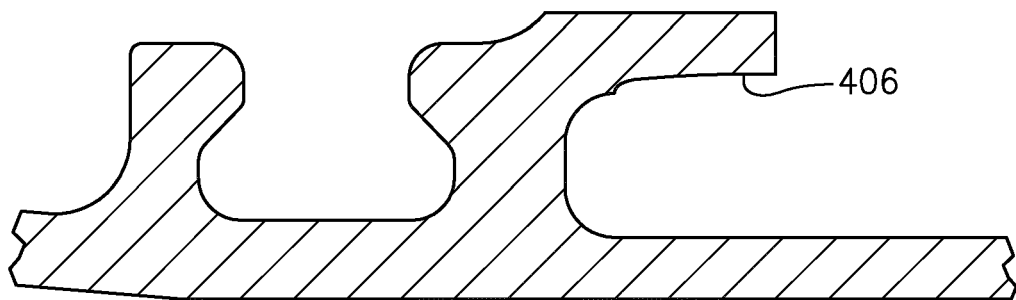


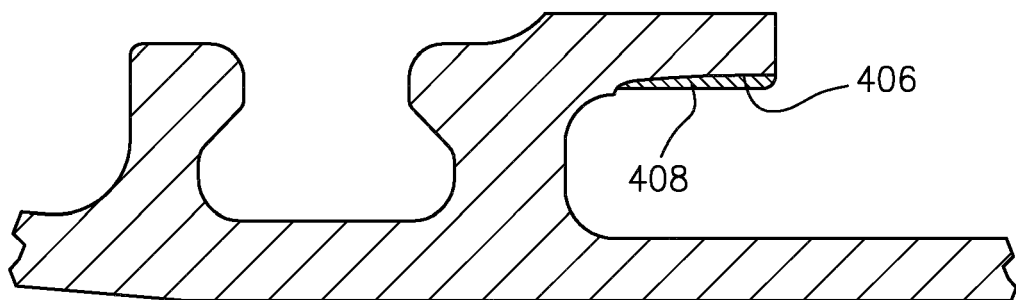
FIG. 3



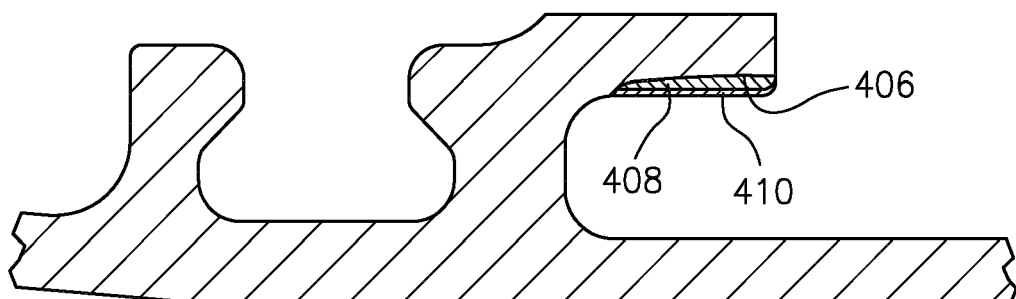
*FIG. 4A*



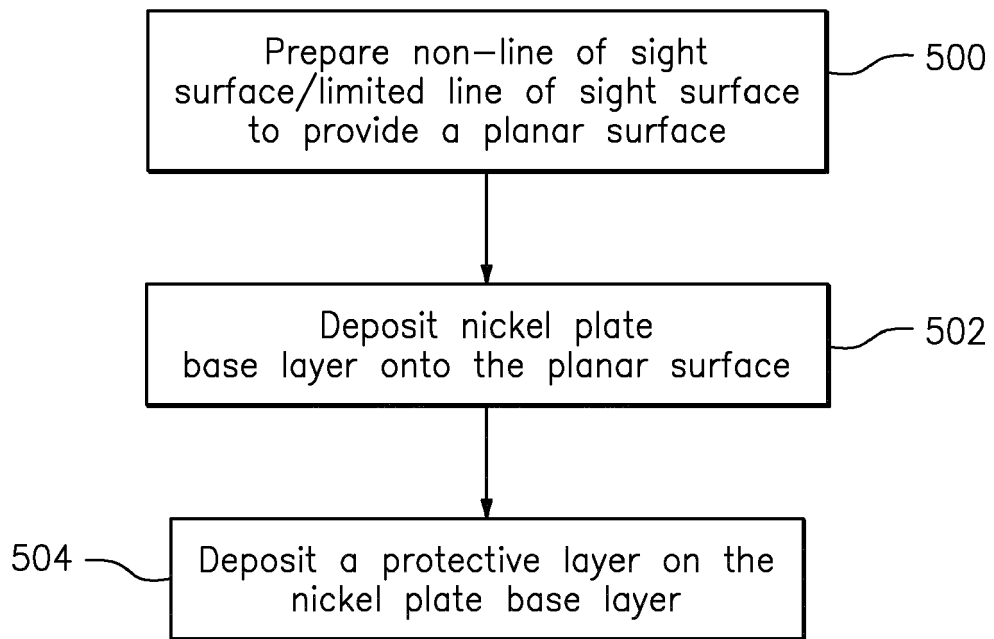
*FIG. 4B*



*FIG. 4C*



*FIG. 4D*



*FIG. 5*



## EUROPEAN SEARCH REPORT

Application Number  
EP 19 19 7228

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The present search report has been drawn up for all claims			
Place of search <b>Munich</b>		Date of completion of the search <b>5 February 2020</b>	Examiner <b>Tsipouridis, P</b>
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT  
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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