Title: METHOD FOR REMOVING A CERAMIC

Abstract: The invention relates to a method for removing a ceramic (13), whereby said ceramic (13) is put into a halogenising/reducing or halogenising/inert atmosphere (A2), containing at least one halogen with a halogen content of 2 vol.-% in maximum and that at least one element or phase of said ceramic (13) is converted to a gaseous species (phase change) in a gaseous process at elevated temperatures (T2) in said atmosphere (A2).
DESCRIPTION

METHOD FOR REMOVING A CERAMIC

BACKGROUND OF THE INVENTION

The present invention relates to the technology of technical ceramics, essentially with regard to gas turbines. It refers to a method for removing a ceramic.

PRIOR ART

The reconditioning scope for gas turbine components depends on the degree of deterioration. In many cases only the ceramic coating needs to be replaced, or the metallic coating needs a re-loading with Al/Cr. Even if the parts just require a heat treatment, the ceramic coating needs to be replaced, since it can deteriorate during a heat treatment, and may have a shorter lifetime than the metallic coating also due to sintering.
For all cases removal of the ceramic coating and a clean surface of the underlying metallic coating is required, without damaging the metallic coating.

Currently, the ceramic coating is removed by grit blasting, taking advantage of the difference in brittleness between the ceramic and the metallic coating (see for example WO 201 1/1 35526 A1 or US 7,805,822 B2 or US 6,908,657 B2). However, due to the abrasive nature of the grit blasting a certain amount of the metallic coating is removed as well, plus cooling air holes might be clogged by grit particles. Furthermore, grit blasting is a very labor-intensive single piece process, which can only remove ceramic coating from line-of-sight location and not, e.g. coating residues in cooling air holes.

To overcome the limits of the mechanical removal of ceramic coating, EP1 0761 14B1 proposes a gaseous process that attacks the interface of the ceramic coating with the underlying metal part. Specifically, the interface needs to be exposed first to the gas. In addition, the interface has to comprise either Al, Ti, Cr, Zr or their oxides in order for the removal process to attack the bond to the ceramic. Thus, this process is limited to specific interfaces and may be rather slow, because the gas has to propagate along the interface rather than being able to attack on the entire surface simultaneously.

Furthermore, the process disclosed in EP1 0761 14B1 uses 6 to 20 wt.-% hydrohalogen gas. According to a preferred embodiment a mixture of 6-14 wt.-% hydrogen fluoride gas (HF) as reactive gas with the balance hydrogen gas is used. While such high concentrations of HF are for sure efficient in cleaning they also attack as a disadvantage the underlying metal, e.g. by depletion of Al, Ti.

When working in reducing atmosphere, which is usually achieved by working in hydrogen (as e.g. disclosed in EP1 0761 14B1 or in DE 10 2008 011 747 A1, where a mixture of 2.5 to 45 vol.-%, preferred 5 to 25 vol.-% HF with the balance H2 is used), care needs to be taken that the oxygen release from the ceramic is significantly slower than the consumption of the released oxygen by the hydrogen. Otherwise, there is a risk of explosion.
Document EP 1 275 753 A 1 describes a method of repairing a part (substrate) covered with a thermal barrier coating and with a metal underlayer of alumina-forming alloy such as MCrAlY or NiAl. In a first step of that method the ceramic layer is removed from the part by a thermochemical treatment under fluorine-containing gas. The thermochemical attack is performed at a temperature close to 1000 °C using HF diluted to 10 % in H2. This relative high HF concentration has the same disadvantage, which has been already described (see above). It is disclosed in EP 1 275 753 A 1 that the fluorine-containing halogen gas penetrates into the ceramic via its pores, attacks the yttria of the ceramic and increases thereby the porosity, encouraging further penetration of the fluorine-containing halogen gas. This causes aluminium to be eliminated from the metal underlayer and from the layer diffused into the periphery of the substrate. By eliminating aluminium the bonds between the metal underlayer and the bottoms of the columns in the ceramic outer layer disappear and the ceramic outer layer flakes off during subsequent cooling of the part..

Another problem is related to cleaning of complicated geometries. Every cooling air structure of a component, e.g. cooling air holes, channels or the like, is prone to contamination or even clogging by dirt/particles/contaminations carried with the cooling air. The severity of the contamination depends on the location of the gas turbine (sea, desert etc.), the maintenance of the air inlet filter system (in case of clogged filters, the filters are by-passed) and the geometry of the cooling air distribution system (channel diameter, length and curvature). Depending on the circumstances drastic contamination can be found.

As a consequence, efficient cleaning of fine cooling air structures is becoming more and more important, since modern/next generation gas turbine components with effusion- or transpiration-cooling are developed (see for example WO 2005/056220 A 1, EP 0 089 155 A2, US 7,402,335 B2, EP 1 155 760 B 1 or EP 0 995 880 B 1).
SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for removing a ceramic, which is time-efficient, automatable, can be used in a batch process that completely removes the ceramic without harming an underlying metallic coating or a metallic base substrate, whereby an underlying surface is perfectly cleaned, allowing application of fresh coating right away.

It is another object of the invention to disclose a process, which provides an efficient way of dissolving contaminations of cooling air structures in gas turbine components, or the like.

These and other objects are obtained by a method according to claim 1.

According to the invention, the method for removing a partially or fully stabilized ceramic is characterized in that said ceramic is put into a halogenising/reducing or halogenising/inert atmosphere, containing at least one halogen with an halogen content of 2 vol.-% in maximum, and that at least one element or phase of said ceramic is converted, for example dissolved or disintegrated, to a gaseous species (phase change) in a gaseous process at elevated temperatures in said atmosphere, wherein the halogen content being sufficient to reduce the content of the stabilizing element or phase of the ceramic below the stability limit of the ceramic. Thus a phase change of the ceramic with change of temperature is caused.

In order to remove the ceramic, but not attack the underlying metal or other material, the halogen content (for example the amount of HF in the reactor) is just enough to reduce the stabilizing element or phase of the partially or fully stabilized ceramic below the minimum necessary to stabilize the ceramic. Thus, upon cooling, the ceramic undergoes a phase change. The volume change associated
with this phase change leads to disintegration of the entire ceramic, even if only parts of the ceramic are destabilized. Therefore, the ceramic spalls very easily.

Specifically, said ceramic is a partially or fully stabilized oxide ceramic. More specifically, said partially or fully stabilized oxide ceramic is zirconia stabilized with a rare earth or an alkaline earth element or combinations thereof.

Even more specifically, said rare earth or alkaline earth element is one of Sc, Y, Sm, Mg, Ca, Ce, Ta or Sr.

According to another embodiment of the invention said ceramic is one of an alkali silicate, alkali borosilicate, earth alkali silicate or earth alkali borosilicate ceramic, or any of those compounds with the addition of a semimetal or metalloid, especially Al or Pb.

According to a further embodiment of the invention said halogen has a higher electronegativity than oxygen, on either Pauling Scale, Mulliken Scale or Allred-Rochow Scale.

Specifically, said halogen is F. According to a further embodiment of the invention, HF content is 1 vol. -% or less.

According to a further embodiment of the invention, HF content is 0.5 vol. - % or less.

More specifically, to achieve said reducing or inert atmosphere, the ceramic is put into H₂ or Ar or N₂ and as reactive halogen F is added as HF gas. The advantage of using an inert atmosphere (Ar or N₂) is that there is no risk of explosion when oxygen is released from the ceramic.
Even more specifically, said elevated temperatures are above 850 °C, preferably between 1000°C and 1150°C.

Alternatively, said halogen may be Cl.

According to another embodiment of the invention said gaseous process takes place in a reactor, which is operated in a pulsed mode through several cycles, whereby in each cycle reaction products of the process are removed from the reactor by pumping out said reducing atmosphere and fresh gas is supplied afterwards.

According to a further embodiment of the invention said gaseous process is run as a batch process, whereby several articles comprising said ceramic are processed at the same time.

According to just another embodiment of the invention said gaseous process is used to separate a ceramic from a metal or underlying ceramic coating layers or substrate.

Specifically, said gaseous process is used to separate a ceramic coating from a metallic or ceramic body or surface.

More specifically, said gaseous process is further used to simultaneously clean the surface of said metallic body or said metallic surface or ceramic surface such that said metallic body or said metallic surface can be brazed without further cleaning or oxide removal and, in case no rework is required, is immediately ready for receiving a fresh ceramic coating.

According to a further embodiment of the invention said gaseous process is used to remove a thermal barrier coating, especially consisting of yttria stabilized zirconia (YSZ) from a component and clean the underlying metallic coating, thereby removing thermally grown oxide and any other oxide scales.
According to a further embodiment of the invention said gaseous process is used to remove an abradable coating consisting of alkali silicate from a component and clean the underlying metallic coating.

According to another embodiment of the invention said gaseous process is used to remove ceramic tiles attached to a base metal by an alkali silicate or yttria stabilized zirconia (YSZ) from a component and clean the underlying metallic coating.

According to just another embodiment of the invention said gaseous process is used to remove a ceramic coating that is connected to a metallic surface by means of rivets, without damaging the delicate riveted structure of the underlying surface.

According to a further embodiment of the invention said gaseous process is used to remove only the outermost layer from a component coated with a multilayer metallic/ceramic coating.

According to another embodiment of the invention said gaseous process is used to remove a contamination, e.g. sand, earth alkali silicates, from effusion- or transpiration-cooled parts, which have a structure exhibiting open porosity.

According to just another embodiment of the invention said gaseous process is used to remove an environmental barrier coating from a ceramic matrix composite (CMC) component.

Finally, the method can be used for the removal of a top coating (EBC= Environmental barrier coating) from a multilayer coating.
BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is now to be explained more closely by means of different embodiments and with reference to the attached drawings.

Fig. 1 shows different steps in a method for removing the thermal barrier coating and cleaning the underlying surface according to an embodiment of the invention;

Fig. 2 shows different steps in a method for removing the ceramic layer from a metallic body in a pulsed process in a reactor according to another embodiment of the invention; and

Fig. 3 shows the removal of a ceramic layer from a "riveted" metallic body without damaging the rivets according to another embodiment of the invention.

DETAILED DESCRIPTION OF DIFFERENT EMBODIMENTS OF THE INVENTION

The invention is related to a gaseous process at elevated temperatures in a halogenising/reducing or halogenising /inert atmosphere containing halogens as reactive species to selectively dissolve and remove partially or fully stabilized ceramics.

During the process the stabilizing phase is removed from the ceramic. As soon as the content of the stabilizing phase decreases below the stability limit, the entire ceramic de-stabilizes and is readily removed or spalls of during the cooling-down phase.
Especially, said process may be applied to partially or fully stabilized oxide ceramics. During the process the stabilizing phase is removed (by phase change) from the oxide ceramic. As soon as the content of the stabilizing phase decreases below the stability limit, the entire oxide ceramic de-stabilizes and is readily removed or spalls of.

Furthermore, said process may be applied to an alkali silicate, alkali borosilicate, earth alkali silicate, earth alkali borosilicate or any of those compounds with the addition of a semimetal or metalloid (e.g. Al, Pb.). During the process, the halogen attacks the Si containing phase, which results in dissolution and removal of the entire ceramic.

Said halogen may be F or Cl. Said partially or fully stabilized oxide ceramic may be zirconia stabilized with a rare earth or an alkaline earth element or combinations thereof, whereby said rare earth or alkaline earth element may be Sc, Y, Sm, Mg, Ca, Ce, Ta or Sr.

When said process is used to separate a ceramic from a metal, e.g. removing a ceramic coating from a metallic surface, said halogen attacks preferably the stabilizing phase. Thus, after dissolving only a few percent of the ceramic, the amount of the stabilizing phase has decreased below the stability limit and the entire ceramic disintegrates. This enables a very efficient removal of the ceramic with a minimum of reactive species.

Fig. 1 shows different steps in a method for removing the thermal barrier coating and cleaning the underlying surface according to an embodiment of the invention. The respective process starts (Fig. 1(a)) with a component 10, which comprises a metallic body, or metallic coating on a component, 11 covered with a thermal barrier coating TBC 13. Between the thermal barrier coating 13 and the metallic body 11 there may be a thermally grown oxide layer 12. Furthermore, Fig. 1 shows an exemplary cooling air hole 25 crossing the layer body and being covered at its inner wall with a contamination 26.
According to Fig. 1(b), the component 10 is put into a reducing, halogen containing atmosphere 14 and heated to temperatures of several hundred °C. Said atmosphere 14 destabilizes the ceramic of the thermal barrier coating 13 and at the same time reduces and finally removes contamination 26 within the cooling air hole 25.

After the thermal barrier coating 13 and the contamination 26 has been removed, the underlying thermally grown oxide layer is removed by the halogenising/reducing atmosphere 14 (Fig. 1(c)).

Finally, the body, or metallic coating on a component, 11 itself remains with a cleaned surface, which is ready to be coated again, and a cleaned cooling air hole 25, which is ready to guide cooling air without obstruction.

The simultaneous cleaning of the metal part allows the metal part to be brazed without further cleaning or oxide removal, and in case no rework of the metal part is required, the part is immediately ready for receiving a fresh ceramic coating. So the process offers a time efficient one step process for coating removal, cleaning, preparation for repair and recoating. As a halogen is a strong oxidizing agent and can thus also dissolve many contaminations.

The invented process is preferably a batch process, not a single piece process, which allows economic ceramic removal for entire sets in very short time.

Fig. 2 shows different steps in a method for removing the ceramic layer from a metallic body in a pulsed process in a reactor according to another embodiment of the invention.

The process starts with a component 20, which comprises a body 21 with a ceramic layer 22 on its upper surface (Fig. 2(a)).
The component 20 is put into a reactor 15, which can be heated by means of a heater 17 (Fig. 2(b)). The inner space 16 of the reactor 15 can be filled with one or more gases through a gas supply line 18, which can be closed by means of valve 23. On the other hand, the inner space 16 can be pumped out or evacuated by means of pump 24 through a pump line 19.

When the process begins at a low temperature $T_1$ (e.g. room temperature), the reactor 15 is heated up to a temperature $T_2$, which is substantially higher than the temperature $T_1$ (Fig. 2(c)).

A first atmosphere $A_1$ containing hydrogen is therefore established in the inner space 16 of the reactor by introducing an inert/reducing gas through the supply line 18 and the valve 23 into the reactor (Fig. 2(d)).

By introducing a reactive halogen, e.g. F, in form of an HF gas, through gas supply line 18, a second reducing atmosphere $A_2$ is established, which begins to destabilize the ceramic layer 22 of the component 20 (Fig. 2(e)).

The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor 15 by pumping out the gas with pump 24 (Fig. 2(f)) and supplying fresh gas afterwards through gas supply line 18 (Fig. 2(g)). Several of such cycles (Fig. 2(f) -> Fig. 2(g) -> Fig. 2(f) -> Fig. 2(g)......) are done, until the ceramic layer 22 is completely removed and the surface of body 21 cleaned (Fig. 2(h)).

In the following, some example of the method according to the invention will be explained.

1. Example:
Removal of a thermal barrier coating:

- Aim: remove a thermal barrier coating 13 consisting of YSZ (yttria stabilized zirconia) from a component 10 and clean the underlying metallic coating (i.e. remove thermally grown oxide 12 and any other oxide scales);
• Process: the parts are put in a reactor 15, which is heated to 1050 °C. To achieve a reducing atmosphere the reactor 15 is flooded with H₂. As reactive halogen, F is introduced as HF gas leading to an HF concentration of 1.5 vol. %. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor by pumping out the gas and supplying fresh gas afterwards. For the second pulse a gas mixture with 1 vol.-% HF is used, for the third pulse one with 0.5 vol.-%. The duration of each pulse is 10 min.
• Result: the YSZ 13 readily disintegrates and detaches from the component, any thermally grown oxides 12 at the ceramic/metallic interface are dissolved as well, and the surface of the metallic coating is cleaned.

3. Example:
Removal of ceramic tiles:
• Aim: remove ceramic tiles attached to a base metal by an alkali silicate from a component and clean the underlying metallic coating;
• Process: the parts are put in a reactor 15, which is heated to 1150°C. To achieve a reducing atmosphere the reactor 15 is flooded with H₂. As reactive halogen, F is introduced as HF gas. The gas mixture has a halogen content of max. 2 vol.-%. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor 15 by pumping out the gas and supplying fresh gas afterwards. Several such cycles are done.
• Result: the alkali silicate is readily dissolved and the surface of the metallic coating is cleaned.
reactive halogen, F is introduced as HF gas leading to an HF concentration of 1.5 vol.-%. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor by pumping out the gas and supplying fresh gas afterwards. Five such cycles of 25 min each are done.

- Result: the joint is readily dissolved and the surface of the metallic coating is cleaned.

4. Example:
Removal of a ceramic coating that is "riveted" to a metallic surface (e.g. as disclosed in US 6,471,881 B1, DE 100 57 187 A1, US 6,074,706 A; US 2002/01 72799 A1, EP 1 491 657 A1):

- Aim: remove a ceramic coating (28 in Fig. 3(a)), without damaging the delicate "riveted" structure of the underlying surface of a metallic body 27 comprising distributed rivets 29 (in this case an abrasive process, or any mechanical cleaning process would damage the delicate structure and herewith the mechanical interlocking that is needed for recoating);
- Process: the parts are put in a reactor 15, which is heated to more than 850^0C, preferably to more than 1000^0C but not more than 1150^0C. To achieve a reducing atmosphere the reactor 15 is flooded with H2. As reactive halogen, F is introduced as HF gas. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor by pumping out the gas and supplying fresh gas afterwards. Several such cycles are done.
- Result: the ceramic coating is efficiently removed and the sophisticated geometry of the underlying surface preserved (Fig. 3(b)).

5. Example:
Selective removal of the top layer from a multilayer coating:

- Aim: removing only the outermost layer (e.g. an YSZ for thermal protection) from a component coated with a multilayer coating (as disclosed for example in US 2005/01 12381 A1).
• Process: the parts are put in a reactor 15, which is heated to more than 850 °C, preferably to more than 1000 °C but not more than 1150 °C. To achieve a reducing atmosphere the reactor 15 is flooded with H₂. As reactive halogen, F is introduced as HF gas. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor by pumping out the gas and supplying fresh gas afterwards. Several such cycles are done.

• Result: the YSZ coating, which formed the outermost thermal protection layer TBC, is readily disintegrated by the gaseous process. The underlying environmental coating based essentially on tantalum oxide and alloyed with lanthanum oxide, is not harmed.

6. Example:
Removal of a ceramic abradable coating from a ceramic component:

• Aim: remove the worn abradable coating from a ceramic component. Due to the brittle nature of the ceramic component, an abrasive process cannot be used;

• Process: the parts are put in a reactor 15, which is heated to more than 850 °C, preferably to more than 1000 °C but not more than 1150 °C. To achieve a reducing atmosphere the reactor 15 is flooded with H₂. As reactive halogen, F is introduced as HF gas. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor by pumping out the gas and supplying fresh gas afterwards. Several such cycles are done.

• Result: the alkali silicate based abradable coating is preferably attacked, whereas the attack on the dense (SiN) component is too slow to damage the part.

7. Example:
Cleaning of effusion- or transpiration-cooled parts or regions of parts, or areas with serpentine cooling (e.g. the cooling air hole 25 of Fig. 1):
• Aim: remove contamination (e.g. sand, earth alkali silicates) from effusion-
or transpiration-cooled parts, which have a structure exhibiting open porosity (e.g. as disclosed in WO 2005/056220 A1, EP 0 089 155 A2, US 7,402,335 B2, EP 1 155 760 B1, EP 0 995 880 B1);

• Process: the parts are put in a reactor 15, which is heated to more than 850°C, preferably to more than 1000°C but not more than 1150°C. To achieve a reducing atmosphere the reactor 15 is flooded with H₂. As reactive halogen, F is introduced as HF gas. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor by pumping out the gas and supplying fresh gas afterwards. Several such cycles are done.

• Result: the fine structures of the effusion-, transpiration- or serpentine-cooling are effectively cleaned.

8. Example
Removal of environmental barrier coating from a ceramic matrix composite (CMC) component:

• Aim: remove a degraded environmental barrier coating from a CMC component;

• Process: the parts are put in a reactor 15, which is heated to more than 850°C, preferably to more than 1000°C but not more than 1150°C. To achieve a reducing atmosphere the reactor 15 is flooded with H₂. As reactive halogen, F is introduced as HF gas. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor by pumping out the gas and supplying fresh gas afterwards. Several such cycles are done.

• Result: the alumino silicate based environmental barrier coating is readily removed, whereas the attack on the underlying CMC component is too slow to cause noticeable material removal.

9. Example
Removal of thermal barrier coating 13 made from YSZ from a component 10:
• Aim: remove the thermal barrier coating from the component without attacking the underlying metal coating;
• Process: the parts are put in a reactor 15, which is heated to 1100°C. The reactor 15 is flooded with Ar. As reactive halogen, F is introduced as HF gas. The reactor 15 is operated in a pulsed mode, i.e. the reaction products are removed from the reactor by pumping out the gas and supplying fresh gas afterwards. Four cycles are done, the first with 2 vol.-% HF, the second with 1.5 vol.-% HF, the third with 1 vol.-% HF, the last with 0.5 vol.-% HF. Each cycle lasts 15 min.
• Result: the YSZ is effectively removed without harming the metallic bond coat, at the same time cleaning the former interface region between the bond coat (underlying metal coating) and the TBC.

The above-described process is a time-efficient, automatable, batch process that completely and selectively removes the ceramic without harming the underlying metallic coating, ceramic or substrate. Additionally, the surface is perfectly cleaned, allowing application of fresh coating right away.

The inventive process furthermore provides an efficient way of dissolving contaminations in cooling air structures because the reactive species is in gaseous form and can therefore reach any location that is reached by the cooling air. Furthermore, the attack on the metal is significantly slower, thus an effective selectivity is achieved.
List of reference numerals

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<tr>
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<tr>
<td>12</td>
<td>thermally grown oxide (TGO) layer</td>
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<td>13</td>
<td>thermal barrier coating (TBC)</td>
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CLAIMS

1. Method for removing a partially or fully stabilized ceramic \((13, 22)\), characterized in that said ceramic \((13, 22)\) is put into a halogenising/reducing or halogenising/inert atmosphere \((A2)\), containing at least one halogen, with a halogen concentration of 2 vol. -% in maximum, and that at least one element or phase of said ceramic \((13, 22)\) is converted to a gaseous species (phase change) in a gaseous process at elevated temperatures \((T2)\) in said atmosphere \((A2)\), wherein the halogen content being just sufficient to reduce the content of the stabilizing element or phase of the ceramic below the stability limit of the ceramic.

2. Method according to claim 1, characterized in that said ceramic \((13, 22)\) is a partially or fully stabilized oxide ceramic.

3. Method according to claim 2, characterized in that said ceramic is zirconia stabilized with a rare earth or an alkaline earth element or combinations thereof.

4. Method according to claim 3, characterized in that said rare earth or alkaline earth element is one of Sc, Y, Sm, Mg, Ca, Ce, Ta or Sr.

5. Method according to claim 1, characterized in that said ceramic \((13, 22)\) is one of an alkali silicate, alkali borosilicate, earth alkali silicate or earth alkali borosilicate ceramic, or any of those compounds with the addition of a semimetal or metalloid, especially Al or Pb.

6. Method according to one of the claims 1 to 5, characterized in that said halogen has a higher electronegativity than oxygen, on either Pauling Scale, Mulliken Scale or Allred-Rochow Scale.
7. Method according to claim 6, characterized in that said halogen is F.

8. Method according to claim 7, characterized in that to achieve said reducing or inert atmosphere, the ceramic (13, 22) is put into H₂ and as reactive halogen F is added as HF gas.

9. Method according to claim 1, characterized in that said elevated temperatures (T2) are above 850 °C, preferably between 1000 °C and 1150 °C.

10. Method according to claim 6, characterized in that said halogen is Cl.

11. Method according to one of the claims 1 to 10, characterized in that said gaseous process takes place in a reactor (15), which is operated in a pulsed mode through several cycles, whereby in each cycle reaction products of the process are removed from the reactor (15) by pumping out said reducing atmosphere (A2) and fresh gas is supplied afterwards.

12. Method according to claim 1, characterized in that said gaseous process is run as a batch process, whereby several articles comprising said ceramic (13, 22) are processed at the same time.

13. Method according to one of the claims 1 to 12, characterized in that said gaseous process is used to separate a ceramic from a metal or underlying ceramic coating layers or substrate.

14. Method according to claim 12, characterized in that said gaseous process is used to separate a ceramic coating (13) from a metallic or ceramic body (11) or surface.

15. Method according to claim 15, characterized in that said gaseous process is further used to simultaneously clean the surface of said metallic body (11) or said metallic surface or ceramic surface such that said metallic body (11) or
said metallic surface can be brazed without further cleaning or oxide removal and, in case no rework is required, is immediately ready for receiving a fresh ceramic coating.

16. Method according to one of the claims 13 to 15, characterized in that said gaseous process is used to remove a thermal barrier coating (13), especially consisting of yttria stabilized zirconia (YSZ) from a component (11) and clean the underlying metallic coating, thereby removing thermally grown oxide (12) and any other oxide scales.

17. Method according to one of the claims 143 to 15, characterized in that said gaseous process is used to remove an abradable coating consisting of alkali silicate or yttria stabilized zirconia (YSZ) from a component and clean the underlying metallic coating.

18. Method according to one of the claims 13 to 15, characterized in that said gaseous process is used to remove ceramic tiles attached to a base metal by an alkali silicate from a component and clean the underlying metallic coating.

19. Method according to one of the claims 13 to 15, characterized in that said gaseous process is used to remove a ceramic coating that is connected to a metallic surface by means of rivets, without damaging the delicate riveted structure of the underlying surface.

20. Method according to one of the claims 1 to 12, characterized in that said gaseous process is used to remove only the outermost layer from a component coated with a multilayer metallic/ceramic coating.

21. Method according to one of the claims 1 to 12, characterized in that said gaseous process is used to remove a contamination (26), e.g. sand, earth alkali silicates, from effusion- or transpiration-cooled parts, which have a structure exhibiting open porosity.
22. Method according to one of the claims 1 to 12, characterized in that said
gaseous process is used to remove an environmental barrier coating from a
ceramic matrix composite (CMC) component.

23. Method according to claim 1, wherein the halogen concentration of the
atmosphere (A2) is 1 vol. % or less.

24. Method according to claim 23, wherein the halogen concentration of the
atmosphere (A2) 0.5 vol. % or less.
Fig. 2
A. CLASSIFICATION OF SUBJECT MATTER

INV. C23G5/00 B23P6/00 C23G1/08

ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols):

C23G B23P

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

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

EPO-Internal, WPI Data, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<td>US 4 889 589 A (MCCOMAS CHARLES C [US]) 26 December 1989 (1989-12-26)</td>
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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: 4 July 2013

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