MASKANT FOR FLUORIDE ION CLEANING

BACKGROUND OF THE INVENTION

[0001] This application relates to a maskant material which protects a surface being subjected to fluoride ion cleaning.

[0002] Gas turbine engines are known, and typically include a compressor which delivers compressed air into a combustor section. A fan may deliver air into the compressor section in some types of turbine engines. In the combustion section, the air is mixed with fuel and ignited. Products of this combustion pass downstream over turbine rotors. The turbine rotors, the compressor, and the fan all included any number of airfoil structures which are subject to stresses both from mechanical and temperature issues.

[0003] It sometimes occurs that a crack may form in one of the airfoil components. Various techniques are known for repairing the cracks in an airfoil. One challenge is that the cracks may occur while the airfoil component is still in service in the turbine engine. Thus, metal oxides may form within the cracks.

[0004] One type of airfoil component is formed of nickel alloys. The nickel may include a small percentage of titanium or aluminum, as an example.

[0005] To remove the oxides in these cracks, fluoride ion cleaning is utilized. In such cleaning, a fluoride ion gas is present in a chamber around the part. The fluoride will combine with the oxides, and the oxides are cleaned from the cracks.

[0006] Unfortunately, when fluoride ion cleaning is utilized with nickel alloy components, it may also remove some of the aluminum or titanium. This can form so-called "intergranular attack" (IGA) at grain boundaries. Essentially, this means that new cracks are formed by the fluoride ion cleaning.

[0007] It has been proposed to provide a layer of nickel on the surface to be treated by fluoride ion cleaning. This layer has been unduly thick, and has also been sacrificial, and thus does not survive the cleaning process.

SUMMARY OF THE INVENTION

[0008] In one featured embodiment, a method of treating a surface includes the steps of providing a plating including at least some nickel over a nickel alloy surface in a

thickness less than 0.0005" (0.001 cm), and exposing the surface to a fluoride ion cleaning to remove impurities on the surface, and leaving at least some of the plating.

[0009] In another embodiment according to the previous embodiment, the nickel alloy includes at least one of aluminum and titanium.

[0010] In another embodiment according to any of the previous embodiments, the fluoride ion cleaning may be hydrogen fluoride ion cleaning.

[0011] In another embodiment according to any of the previous embodiments, the surface is part of a component having a crack with oxides to be cleaned by the fluoride ion cleaning.

[0012] In another embodiment according to any of the previous embodiments, the component has an airfoil.

[0013] In another embodiment according to any of the previous embodiments, the component is a gas turbine engine component.

[0014] In another embodiment according to any of the previous embodiments, the nickel plating is deposited in a thickness that is generally less than a depth of the crack.

[0015] In another embodiment according to any of the previous embodiments, the crack is repaired after the fluoride ion cleaning.

[0016] In another embodiment according to any of the previous embodiments, the component has internal cavities, and an inner wall spaced inwardly from an outer wall. The crack is in the inner wall, and the plating is the inner wall is done with an electroless plating technique.

[0017] In another embodiment according to any of the previous embodiments, the plating is provided by a nickel alloy.

[0018] In another embodiment according to any of the previous embodiments, the crack extending from the inner wall to the outer wall, and the plating is done on both the outer wall and the inner wall.

[0019] In another embodiment according to any of the previous embodiments, the nickel plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

[0020] In another embodiment according to any of the previous embodiments, the plating is deposited in a thickness that is generally less than the depth of the crack.

[0001] In another embodiment according to any of the previous embodiments, the plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

[0002] In another featured embodiment, a method of repair includes the steps of providing a plating including at least some nickel over a nickel alloy component that has a crack to be repaired the plating being less than 0.0005" (0.001 cm) thick, exposing the component to a fluoride ion cleaning to remove impurities in the crack, and leaving at least some of the plating, and repairing the crack in the component.

[0003] In another embodiment according to the previous embodiment, the component has internal cavities, and an inner wall spaced inwardly from an outer wall. The crack is in the inner wall, and the plating is done on the inner wall with electroless plating technique.

[0004] In another embodiment according to any of the previous embodiments, the plating is provided by a nickel alloy.

[0005] In another embodiment according to any of the previous embodiments, the nickel plating is deposited in a thickness that is generally less than the depth of the crack.

[0006] In another embodiment according to any of the previous embodiments, the nickel plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

[0007] In another featured embodiment, a gas turbine engine component has an airfoil formed of a nickel alloy include at least one or aluminum and titanium, and nickel plating over a surface of the airfoil, deposited in a thickness of greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm), and a repaired crack.

[0008] These and other features of this application will be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 shows an example airfoil component.

[0010] Figure 2 shows a crack.

[0011] Figure 3 shows the method steps associated with this application.

[0012] Figure 4 shows an example airfoil component after the method of Figure 3 is complete.

[0013] Figure 5 shows example areas of a component.

[0014] Figure 6 shows another application.

DETAILED DESCRIPTION

[0015] A component 20 is illustrated in Figure 1. Component 20 may be a turbine blade or a turbine vane. As known, component 20 has an airfoil shape.

[0016] A crack 22 is shown in a surface. The crack must be repaired before the part is returned for service. Various techniques are known for repairing the cracks, and any one of the actual methods for repairing may benefit from the teachings of this application.

[0017] A problem addressed by this application may be understood from Figure 2. As shown in Figure 2, the crack 22 will develop metal oxides as shown at 23. This occurs as the component 20 will typically remain in service after the crack occurs, and thus, the exposed surfaces in the crack will form oxides. In one embodiment, the component 20 is formed of nickel alloy, and may contain materials in addition to nickel, such as aluminum and titanium.

[0018] As mentioned above, it is known to use a fluoride ion cleaning technique to remove the oxides 23 from the crack 22 prior to repair of the crack.

[0019] One known fluoride ion cleaning technique is hydrogen fluoride gas cleaning. However, other fluoride ion techniques may be utilized in this method. One example alternative method is fluorocarbon cleaning.

[0020] As also mentioned above, with the use of the fluoride ion cleaning, inter-granular attack may cause new cracks in the component 20 at grain boundaries.

[0021] Figure 3 shows a method of repairing the component while avoiding intergranular attack. First, the component 20 may be cleaned as shown at 60.

[0022] Then, a nickel plating 61 is placed on the component 20. While the nickel plating 61 may occur at all areas of the component, it may also only be utilized at areas which are subject to the most stress, if that is more economical.

[0023] In one embodiment, the nickel plating may be plated by compound electroplating. The nickel plate may be deposited to a thickness of greater than or equal to about .0001" (.000254 cm) to less than or equal to about 0.0005" (0.001 cm). More narrowly,

the thickness may be less than or equal to about 0.0002" (0.005 cm). A surface 19 of the component 20 is shown with the nickel plating 70.

[0024] As shown, the crack 22 is typically much thicker than the thickness of the nickel plating, and thus the nickel plating will not block access to the crack during the fluoride ion cleaning 62. Further, the nickel plating 70 will likely not adhere to the oxide materials 23 in the crack 22. Finally, should it be determined that the nickel plating does complicate the cleaning of the crack 22, the crack 22 may be masked during the plating process.

[0025] As mentioned, the plated component has been subject to fluoride ion cleaning at 62. This cleaning technique may be as known, and remove the oxides 23. The plating 70 is intended to survive the cleaning process, at least in part, such that it is on the final cleaned component.

[0026] Some repair 63 is then utilized to repair the crack and restore the component 20. Braze repairs are but one example of a method that may be utilized.

[0027] As shown at Figure 4, the component 120 will now be ready for return to service.

[0028] As can be seen from Figure 5, a portion of a material 200 shows the effect of fluoride ion cleaning on an area that has been plated. This can be contrasted to an area 202 wherein plating did not occur. As can be seen in area 202, a number of cracks can be seen at 205. These cracks are the result of intergranular attack. Similar cracks are not found in area 200.

[0029] Figure 6 shows another application to the component 20. As known, airfoil components such as component 20 have an outer wall 300, but also tend to have internal cavities such as shown at 299. These cavities pass cooling air within the component. A crack 302 is shown on an inner wall 301 of component 20. A layer 304 may be applied to the surface 301 prior to cleaning of the crack 302. When utilized on an inner surface, electroless plating techniques may be necessary. Further, when utilized with electroless plating techniques, nickel alloys, such as nickel-boron, or nickel-phosphorous, may be utilized.

[0030] The thickness of the layer 304 may be generally the same as the thicknesses as mentioned above for the external layer.

[0031] Another potential situation is illustrated in Figure 6, and wherein the crack has a portion 402 extending to the outer wall or surface 300. In this embodiment, a layer 400 would also be placed on the outer wall 300, such that the combined crack 302 and 402 can be repaired.

[0032] While the specific disclosure here is to a repair process, the method may provide benefits to any fluoride ion cleaning of a nickel alloy surface.

[0033] Although an embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

CLAIMS

1. A method of treating a surface comprising the steps of:

a) providing a plating including at least some nickel over a nickel alloy surface in a thickness less than 0.0005" (0.001 cm); and

b) exposing said surface to a fluoride ion cleaning to remove impurities on the surface, and leaving at least some of said plating.

2. The method as set forth in claim 1, wherein said nickel alloy includes at least one of aluminum and titanium.

3. The method as set forth in claim 2, wherein said fluoride ion cleaning may be hydrogen fluoride ion cleaning.

4. The method as set forth in claim 3, wherein said surface is part of a component having a crack with oxides to be cleaned by said fluoride ion cleaning.

5. The method as set forth in claim 4, wherein said component has an airfoil.

6. The method as set forth in claim 5, wherein said component is a gas turbine engine component.

7. The method as set forth in claim 4, wherein said nickel plating is deposited in a thickness that is generally less than a depth of said crack.

8. The method as set forth in claim 4, wherein said crack is repaired after said fluoride ion cleaning.

9. The method as set forth in claim 4, wherein said component has internal cavities, and an inner wall spaced inwardly from an outer wall, and said crack is in said inner wall, and the plating of step (a) on said inner wall is done with electroless plating technique.

10. The method as set forth in claim 9, wherein said plating is provided by a nickel alloy.

11. The method as set forth in claim 9, wherein said crack extending from said inner wall to said outer wall, and the plating of step (a) is done on both said outer wall and said inner wall.

12. The method as set forth in claim 4, wherein a thickness of said nickel plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

13. The method as set forth in claim 1, wherein said plating is deposited in a thickness that is generally less than the depth of said crack.

14. The method as set forth in claim 13, wherein a thickness of said plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

15. A method of repair comprising the steps of:

a) providing a plating including at least some nickel over a nickel alloy component that has a crack to be repaired the plating being less than 0.0005" (0.001 cm) thick;

b) exposing said component to a fluoride ion cleaning to remove impurities in the crack, and leaving at least some of said plating; and

c) repairing the crack in the component.

16. The method as set forth in claim 15, wherein said component has internal cavities, and an inner wall spaced inwardly from an outer wall, and said crack is in said inner wall, and the plating of step (a) is done on said inner wall with electroless plating technique.

17. The method as set forth in claim 16, wherein said plating is provided by a nickel alloy.

18. The method as set forth in claim 15, wherein said nickel plating is deposited in a thickness that is generally less than the depth of said crack.

19. The method as set forth in claim 15, wherein a thickness of said nickel plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

20. A gas turbine engine component comprising:

an airfoil formed of a nickel alloy include at least one or aluminum and titanium; and

nickel plating over a surface of said airfoil, said nickel plating being deposited in a thickness of greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm); and

a repaired crack.

MASKANT FOR FLUORIDE ION CLEANING

BACKGROUND OF THE INVENTION

[0001] This application relates to a maskant material which protects a surface being subjected to fluoride ion cleaning.

[0002] Gas turbine engines are known, and typically include a compressor which delivers compressed air into a combustor section. A fan may deliver air into the compressor section in some types of turbine engines. In the combustion section, the air is mixed with fuel and ignited. Products of this combustion pass downstream over turbine rotors. The turbine rotors, the compressor, and the fan all included any number of airfoil structures which are subject to stresses both from mechanical and temperature issues.

[0003] It sometimes occurs that a crack may form in one of the airfoil components. Various techniques are known for repairing the cracks in an airfoil. One challenge is that the cracks may occur while the airfoil component is still in service in the turbine engine. Thus, metal oxides may form within the cracks.

[0004] One type of airfoil component is formed of nickel alloys. The nickel may include a small percentage of titanium or aluminum, as an example.

[0005] To remove the oxides in these cracks, fluoride ion cleaning is utilized. In such cleaning, a fluoride ion gas is present in a chamber around the part. The fluoride will combine with the oxides, and the oxides are cleaned from the cracks.

[0006] Unfortunately, when fluoride ion cleaning is utilized with nickel alloy components, it may also remove some of the aluminum or titanium. This can form so-called “intergranular attack” (IGA) at grain boundaries. Essentially, this means that new cracks are formed by the fluoride ion cleaning.

[0007] It has been proposed to provide a layer of nickel on the surface to be treated by fluoride ion cleaning. This layer has been unduly thick, and has also been sacrificial, and thus does not survive the cleaning process.

SUMMARY OF THE INVENTION

[0008] In one featured embodiment, a method of treating a surface includes the steps of providing a plating including at least some nickel over a nickel alloy surface in a

thickness less than 0.0005" (0.001 cm), and exposing the surface to a fluoride ion cleaning to remove impurities on the surface, and leaving at least some of the plating.

[0009] In another embodiment according to the previous embodiment, the nickel alloy includes at least one of aluminum and titanium.

[0010] In another embodiment according to any of the previous embodiments, the fluoride ion cleaning may be hydrogen fluoride ion cleaning.

[0011] In another embodiment according to any of the previous embodiments, the surface is part of a component having a crack with oxides to be cleaned by the fluoride ion cleaning.

[0012] In another embodiment according to any of the previous embodiments, the component has an airfoil.

[0013] In another embodiment according to any of the previous embodiments, the component is a gas turbine engine component.

[0014] In another embodiment according to any of the previous embodiments, the nickel plating is deposited in a thickness that is generally less than a depth of the crack.

[0015] In another embodiment according to any of the previous embodiments, the crack is repaired after the fluoride ion cleaning.

[0016] In another embodiment according to any of the previous embodiments, the component has internal cavities, and an inner wall spaced inwardly from an outer wall. The crack is in the inner wall, and the plating is the inner wall is done with an electroless plating technique.

[0017] In another embodiment according to any of the previous embodiments, the plating is provided by a nickel alloy.

[0018] In another embodiment according to any of the previous embodiments, the crack extending from the inner wall to the outer wall, and the plating is done on both the outer wall and the inner wall.

[0019] In another embodiment according to any of the previous embodiments, the nickel plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

[0020] In another embodiment according to any of the previous embodiments, the plating is deposited in a thickness that is generally less than the depth of the crack.

[0001] In another embodiment according to any of the previous embodiments, the plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

[0002] In another featured embodiment, a method of repair includes the steps of providing a plating including at least some nickel over a nickel alloy component that has a crack to be repaired the plating being less than 0.0005" (0.001 cm) thick, exposing the component to a fluoride ion cleaning to remove impurities in the crack, and leaving at least some of the plating, and repairing the crack in the component.

[0003] In another embodiment according to the previous embodiment, the component has internal cavities, and an inner wall spaced inwardly from an outer wall. The crack is in the inner wall, and the plating is done on the inner wall with electroless plating technique.

[0004] In another embodiment according to any of the previous embodiments, the plating is provided by a nickel alloy.

[0005] In another embodiment according to any of the previous embodiments, the nickel plating is deposited in a thickness that is generally less than the depth of the crack.

[0006] In another embodiment according to any of the previous embodiments, the nickel plating is greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm).

[0007] In another featured embodiment, a gas turbine engine component has an airfoil formed of a nickel alloy include at least one or aluminum and titanium, and nickel plating over a surface of the airfoil, deposited in a thickness of greater than or equal to about 0.0001" (0.000254 cm) and less than or equal to about 0.0002" (0.0005 cm), and a repaired crack.

[0008] These and other features of this application will be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 shows an example airfoil component.

[0010] Figure 2 shows a crack.

[0011] Figure 3 shows the method steps associated with this application.

[0012] Figure 4 shows an example airfoil component after the method of Figure 3 is complete.

[0013] Figure 5 shows example areas of a component.

[0014] Figure 6 shows another application.

DETAILED DESCRIPTION

[0015] A component 20 is illustrated in Figure 1. Component 20 may be a turbine blade or a turbine vane. As known, component 20 has an airfoil shape.

[0016] A crack 22 is shown in a surface. The crack must be repaired before the part is returned for service. Various techniques are known for repairing the cracks, and any one of the actual methods for repairing may benefit from the teachings of this application.

[0017] A problem addressed by this application may be understood from Figure 2. As shown in Figure 2, the crack 22 will develop metal oxides as shown at 23. This occurs as the component 20 will typically remain in service after the crack occurs, and thus, the exposed surfaces in the crack will form oxides. In one embodiment, the component 20 is formed of nickel alloy, and may contain materials in addition to nickel, such as aluminum and titanium.

[0018] As mentioned above, it is known to use a fluoride ion cleaning technique to remove the oxides 23 from the crack 22 prior to repair of the crack.

[0019] One known fluoride ion cleaning technique is hydrogen fluoride gas cleaning. However, other fluoride ion techniques may be utilized in this method. One example alternative method is fluorocarbon cleaning.

[0020] As also mentioned above, with the use of the fluoride ion cleaning, inter-granular attack may cause new cracks in the component 20 at grain boundaries.

[0021] Figure 3 shows a method of repairing the component while avoiding intergranular attack. First, the component 20 may be cleaned as shown at 60.

[0022] Then, a nickel plating 61 is placed on the component 20. While the nickel plating 61 may occur at all areas of the component, it may also only be utilized at areas which are subject to the most stress, if that is more economical.

[0023] In one embodiment, the nickel plating may be plated by compound electroplating. The nickel plate may be deposited to a thickness of greater than or equal to about .0001 inch (.000254 cm) to less than or equal to about 0.0005 inch (0.00127 cm). More narrowly, the thickness may be less than or equal to about 0.0002 inch (0.000508 cm). A surface 19 of the component 20 is shown with the nickel plating 70.

[0024] As shown, the crack 22 is typically much thicker than the thickness of the nickel plating, and thus the nickel plating will not block access to the crack during the fluoride ion cleaning 62. Further, the nickel plating 70 will likely not adhere to the oxide materials 23 in the crack 22. Finally, should it be determined that the nickel plating does complicate the cleaning of the crack 22, the crack 22 may be masked during the plating process.

[0025] As mentioned, the plated component has been subject to fluoride ion cleaning at 62. This cleaning technique may be as known, and remove the oxides 23. The plating 70 is intended to survive the cleaning process, at least in part, such that it is on the final cleaned component.

[0026] Some repair 63 is then utilized to repair the crack and restore the component 20. Braze repairs are but one example of a method that may be utilized.

[0027] As shown at Figure 4, the component 120 will now be ready for return to service.

[0028] As can be seen from Figure 5, a portion of a material 200 shows the effect of fluoride ion cleaning on an area that has been plated. This can be contrasted to an area 202 wherein plating did not occur. As can be seen in area 202, a number of cracks can be seen at 205. These cracks are the result of intergranular attack. Similar cracks are not found in area 200.

[0029] Figure 6 shows another application to the component 20. As known, airfoil components such as component 20 have an outer wall 300, but also tend to have internal cavities such as shown at 299. These cavities pass cooling air within the component. A crack 302 is shown on an inner wall 301 of component 20. A layer 304 may be applied to the surface 301 prior to cleaning of the crack 302. When utilized on an inner surface, electroless plating techniques may be necessary. Further, when utilized with

electroless plating techniques, nickel alloys, such as nickel-boron, or nickel-phosphorous, may be utilized.

[0030] The thickness of the layer 304 may be generally the same as the thicknesses as mentioned above for the external layer.

[0031] Another potential situation is illustrated in Figure 6, and wherein the crack has a portion 402 extending to the outer wall or surface 300. In this embodiment, a layer 400 would also be placed on the outer wall 300, such that the combined crack 302 and 402 can be repaired.

[0032] While the specific disclosure here is to a repair process, the method may provide benefits to any fluoride ion cleaning of a nickel alloy surface.

[0033] Although an embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

CLAIMS

1. A method of treating a nickel alloy surface comprising the steps of:

a) plating a nickel alloy surface with a plating material including at least some nickel for a thickness greater than or equal to 0.0001 inch (.000254 cm) and less than 0.0005 inch (0.00127 cm);

b) then exposing said nickel alloy surface to a fluoride ion cleaning to remove impurities on the surface, and leaving at least some of said plating material; and

c) said nickel alloy surface including at least one of aluminum and titanium, said fluoride ion cleaning being hydrogen fluoride ion cleaning, said nickel alloy surface being part of a component having a crack with oxides to be cleaned by said hydrogen fluoride ion cleaning, said component having internal cavities, and an inner wall spaced inwardly from an outer wall, and said crack being in said inner wall, and the plating step (a) is done on said inner wall.

2. The method as set forth in claim 1, wherein said component has an airfoil.

3. The method as set forth in claim 2, wherein said component is a gas turbine engine component.

4. The method as set forth in claim 1, wherein said nickel plating is deposited in a thickness that is generally less than a depth of said crack.

5. The method as set forth in claim 1, wherein said crack is repaired after said fluoride ion cleaning.

6. The method as set forth in claim 1, wherein the plating is done with an electroless plating technique.

7. The method as set forth in claim 6, wherein said plating is provided by a nickel alloy.

8. The method as set forth in claim 6, wherein said crack extends from said inner wall to said outer wall, and the plating of step (a) is done on both said outer wall and said inner wall.

9. The method as set forth in claim 1, wherein the thickness of said nickel plating is less than or equal to about 0.0002 inch (0.000508 cm).

10. The method as set forth in claim 1, wherein said plating is deposited in a thickness that is generally less than the depth of said crack.

11. The method as set forth in claim 10, wherein the thickness of said plating is less than or equal to about 0.0002 inch (0.000508 cm).

12. A method of repair comprising the steps of:

a) plating a nickel alloy component that has a crack to be repaired with a plating material including at least some nickel, the plating being greater than or equal to about 0.0001 inch (0.000254 cm) and less than 0.0005 inch (0.00127 cm) thick;

b) exposing said component to a fluoride ion cleaning to remove impurities in the crack, and leaving at least some of said plating;

c) repairing the crack in the component; and

d) wherein said nickel plating is deposited in a thickness that is generally less than the depth of said crack.

13. The method as set forth in claim 12, wherein said component has internal cavities, and an inner wall spaced inwardly from an outer wall, and said crack is in said inner wall, and the plating of step (a) is done on said inner wall with electroless plating technique.

14. The method as set forth in claim 13, wherein said plating is provided by a nickel alloy.

15. The method as set forth in claim 12, wherein said nickel plating is deposited in a thickness that is generally less than the depth of said crack.

16. The method as set forth in claim 12, wherein a thickness of said nickel plating is less than or equal to about 0.0002 inch (0.000508 cm).

17. The method as set forth in claim 1, wherein said nickel plating being deposited in a thickness less than or equal to about 0.0002 inch (0.000508 cm).