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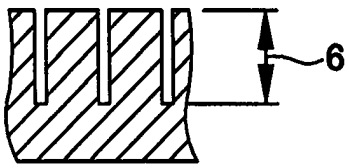
(54) Title: ABRADABLE SEAL

(57) Abstract

An abradable seal is provided utilizing a laser to cut a pattern into the surface effective to improve abradability in the area of the pattern.



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Abradable Seal

Background of the Invention

This invention relates to abradable seals, more particularly to the use of a laser to texture the surface of a seal material to provide improved abradability.

The efficiency of modern gas turbine engines depends upon a tight seal between the rotating components (blades) and the stationary component (shroud) in the fan, compressor and turbine. This seal is established by allowing the blades to cut (abrade) a groove in an abradable seal material which prevents a substantial volume of air from leaking past the blade tip. Traditionally the seal materials have been fabricated from woven metallic fibers or sintered metallic particles and brazed in place. While these materials are easily abraded due to their high internal porosity and low strength, their resistance to particle erosion is poor which results in rapid loss of material. This loss of material degrades the seal and the efficiency of the engine rapidly decreases. Seal materials in the more advanced engine utilize thermal sprayed coatings which perform the same function as the braided abradable seals, but which are easier to apply and easier to replace when an engine is overhauled. The properties of these sprayed seals can be varied to either maximize erosion resistance or maximize abradability. However, it has not been possible to maximize these two properties simultaneously.

The use of thermal spray powders to form abradable seals is known in the art as shown by U.S. Patent 4,291,089. Such powders are used to form a coating on a substrate to provide an abradable seal, that is to say a coating which seals the space between the substrate and an adjacent surface movable relative thereto, and which is abraded to a controlled extent by relative movement between the substrate and the adjacent surface. Such a seal is initially formed by thermal spraying a powder onto the substrate to form a coating with a slightly greater thickness than the spacing between the substrate and the adjacent surface, so that the coating is abraded by relative movement

between the substrate and the adjacent surface to a slightly lesser thickness corresponding to the spacing between the substrate and the adjacent surface so as to provide an efficient seal there between. Such seals are used for example on turbine or compressor blades of gas turbine engines, such as those used in aircraft, to provide a seal between the blades and the turbine or compressor housing.

One of the problems in providing a suitable abradable seal is to produce a thermally sprayed coating which, on the one hand has sufficient structural strength which nevertheless is low enough to provide abradability, and which, on the other hand, has a sufficiently high resistance to erosion by particles impinging on the abradable seal coating during use. For example, in the case of gas turbine or compressor blades, the seal coating is subjected to impingement by abrasive particles entrained in the air and ingested by the engine.

In one type of powder used to form abradable seal coatings, each powder particle has a central core of non-metallic solid material surrounded by a layer of metallic material, as described for example in U.S. Patent No. 3,914,507. Such powders are known as composite powders, with the powder particles being known as composite powder particles. One composite powder of this kind which has been suggested has particles each having a core surrounded by nickel or nickel alloy, and abradable seal coatings formed by thermal spraying such powders have been useful as abradable seal coatings on compressors and turbines of aircraft gas turbine engines.

Summary of the Invention

Briefly, this invention provides an abradable seal and a process for preparing an abradable seal comprising cutting a pattern with a laser into the surface of an abradable seal material effective to provide improved abradability in the area of the pattern.

Brief Description of the Drawings

Embodiments of this invention will now be described, by way of example, with reference to the accompanying drawings, of which:

Figures 1-3 are drawings of a gas turbine engine compressor shroud ring having an abradable seal coating thereon with a cross hatched pattern, with Figure 1 being a top plan view, Figure 2 being a side plan view and Figure 3 an enlarged portion of the abradable seal from Figure 2.

Figures 4-6 are drawings of a gas turbine engine compressor shroud ring having an abradable seal coating thereon with a tubular cell pattern, with Figure 4 being a top plan view, Figure 5 being a side plan view and Figure 6 an enlarged portion of the abradable seal from Figure 5.

Figures 7-10 are embodiments of alternative patterns with Figure 7 showing a top plan view of striped pattern with Figure 8 a cross sectional view of Figure 7, and Figure 9 showing a top plan view of a slanted striped pattern with Figure 10 a cross sectional view of Figure 9.

Figure 11 shows a top plan view of a pattern produced by Example 1.

Figure 12 shows a top plan view of a pattern produced by Example 2.

Detailed Description of the Invention

An abradable seal is prepared with the use of a laser to cut a pattern into the surface of an abradable seal material. Laser texturing provides a means of modifying the surface of an abradable seal material which has good erosion resistance, but requires improved abradability in the area. This surface modification is a pattern, for example of closely spaced holes, a cross hatch pattern, a tubular cell pattern, a striped or slanted striped pattern, a pattern of lines running perpendicular or parallel to the seal or other patterns which also enhance abradability. Various patterns are shown in the Figures. The texturing could also be accomplished across the width of the seal contact area to further enhance the abradability in the area. This invention allows an erosion resistant abradable seal material to be modified to incorporate good abradability in the same product. Existing abradable seals do not possess these characteristics.

The abradable seal material can be a thermal spray coating, or a prefabricated sheet (panel) which is attached to a component by sintering or brazing, or other materials as are known in the art. Advantageously a more

erosion resistant seal material can be utilized since by this invention improved abradability can be imparted to this material by laser texturing. Gas turbine engine components are typically of a nickel-based, cobalt-based, iron-based or titanium based alloy. The abradable seal material can also be of an aluminum-based, titanium-based, iron-based, nickel-based or cobalt-based alloy or can be made of erosion resistant materials including NiCr alloys, NiCrAl alloys, FeCr, CoCr, FeCrAl, CoCrAl, or MCrAlY alloys where M could be Fe, Ni or Co, oxides, nitrides, borides, sulphides, silicides and intermetallics. It is even possible to utilize the component surface itself as the abradable seal material. In one embodiment the abradable seal material can also contain non-metallic particles, including boron nitrides, bentonite, oxide, nitride, borides, silicides, intermetallics, and non metallics e.g. plastics, polymers etc.

Laser texturing is used to cut into the surface of the abradable seal material a pattern which will impart improved abradability to the material. Various patterns are effective including circles, cross hatches and stripes as shown in Figures 1-10. Figures 1-3 show use of a cross-hatched pattern cut into the abradable seal material. Figures 3-6 show a tubular cell (circles) pattern while Figures 7-10 show stripes cut into the surface. The selection of the specific pattern is dependent on the particular seal material and the degree of abradability required. The pattern is also cut into the material in the area and to a depth that the blade is expected to cut (abrade) during operation. Typically the depth of the pattern would be from about 0.01 to 0.1 inches, while the width of the pattern can vary depending upon the blade and can be from 0.125 to 24 inches. In one embodiment, uncut material (i.e. no pattern) remains on two sides of the pattern, i.e. on the edges of the expected blade path, to provide increased erosion resistance during operation of the gas turbine engine. In the Figures the abradable seal material 1 is shown on a shroud ring 2 of a compressor with a pattern 3 being cut into the area of the blade path 4. Additional areas of uncut (no pattern) abradable seal material 5 is shown on both sides of the pattern 3. In Figures 3 and 6 the depth 6 of the pattern corresponds with the expected depth of blade incursion.

A standard laser may be used to cut the pattern. A typical laser is a Raytheon SS550 YAG laser equipped with a 5 axis motion controller operated at approximately 0.5 kilowatt.

Example 1

The surface of a 304 stainless steel plate approximately 1.5 inches wide and 4 inches long and .100 thick was mechanically roughened using 60 mesh aluminum oxide in an aspirated grit blast cabinet. The plate was thermal sprayed coated with a bondcoat of Ni-5wt%Al to a thickness of .004-.006 inches thick. The surface of the bondcoat was then thermal sprayed coated with NiCrAl bentonite (an abradable coating) to a thickness of approximately .150 inches. The surface of the abradable coating was machined to produce a surface which was essentially flat and uniform in surface roughness.

The coated plate was mounted in the jaws on the computer controlled X-Y table of the laser. A computer program was written and loaded in the computer which produced a diagonal traverse pattern at approximately 45° and separated by about .050 inches as shown in Figure 11. The laser was energized and allowed to engrave the surface of the abradable coating to a depth of approximately .050 inches.

Example 2

The surface of a 304 stainless steel plate approximately 1.5 inches wide and 4 inches long and .100 thick was mechanically roughened using 60 mesh aluminum oxide in an aspirated grit blast cabinet. The plate was thermal sprayed coated with a bondcoat of Ni-5wt%Al to a thickness of .004-.006 inches thick. The surface of the bondcoat was then thermal sprayed coated with NiCrAl bentonite (an abradable coating) to a thickness of approximately .150 inches. The surface of the abradable coating was machined to produce a surface which was essentially flat and uniform in surface roughness.

The coated plate was mounted in the clamping fixture on the computer controlled X-Y table of the laser. A program was written and loaded in the computer which produced a motion which moved the coated plate in a linear manner across the surface. The motion was stopped every .050 inches and

activated the laser to fire. At the end of the traverse length the plate was indexed .050 inches in the perpendicular direction and an offset of .025 inches was incorporated in the traverse in order to place the next row of holes in between the previous row. This pattern was repeated until the surface was completely traversed and engraved with the pattern shown in Figure 12. The holes produced were spaced approximately .050 inches and were approximately .050 inches deep.

What is claimed:

1. A process for preparing an abradable seal for a component comprising:

cutting a pattern with a laser into the surface of an abradable seal material effective to provide improved abradability in the area of the pattern.

2. Process of Claim 1 further comprising:

applying an abradable seal material to the component with the pattern being cut into the surface of the seal material.

3. Process of Claim 2 wherein the component and the abradable seal material are metallic.

4. Process of Claim 3 wherein the component is a gas turbine engine component and is an alloy selected from the group consisting of a nickel-based, cobalt-based, iron-based, aluminum-based and titanium-based alloys.

5. Process of Claim 4 wherein the abradable seal material is an alloy selected from the group consisting of iron-based alloys, aluminum-based alloys, titanium-based alloys, nickel-based alloys, cobalt-based alloys, NiCr alloy, NiCrAl alloy and MCrAlY alloys where M is selected from the group consisting of Fe, Ni or Co or mixtures thereof.

6. Process of Claim 5 wherein the abradable seal material contains non-metallic particles.

7. Process of Claim 6 wherein the non-metallic particles are selected from the group consisting of boron nitride, bentonite, oxides, nitrides, borides, silicides, intermetallics, plastics and polymers.

8. Process of Claim 4 wherein the pattern is in an area and to a depth which a blade will abrade in creating a seal.

9. Process of Claim 8 wherein the depth of the pattern is within the range of about 0.01 to 0.1 inches.

10. Process of Claim 9 wherein the pattern is selected from the group consisting of closely spaced holes, cross hatch, stripes, and lines perpendicular or parallel to the seal.

11. Process of Claim 4 comprising applying the abradable seal material by thermal spraying a metallic alloy powder.

12. Process of Claim 4 comprising applying the abradable seal material by attaching a sheet of seal material to the component.

13. Process of Claim 8 wherein there is uncut seal material on two sides of the pattern.

14. An abradable seal comprising:

a pattern cut into the surface of an abradable seal material with a laser effective to provide improved abradability in the area of the pattern.

15. Seal of Claim 14 wherein the seal material is a metallic alloy.

16. Seal of Claim 15 wherein the metallic alloy is selected from the group consisting of iron-based alloy, aluminum-based alloy, titanium-based alloy, nickel-based alloy, cobalt-based alloy, NiCr alloy, NiCrAl alloy and MCrAlY alloy where M is selected from the group consisting of Fe, Ni, or Co.

17. Seal of Claim 15 wherein the abradable seal material contains non-metallic particles.

18. Seal of Claim 17 wherein the non-metallic particles are selected from the group consisting of boron nitride, bentonite, oxides, nitrides, borides, silicides, intermetallic compounds, plastics and polymers.

19. Seal of Claim 15 wherein the abradable seal material is in the form of a sheet adapted to be attached to a gas turbine engine component.

20. Seal of Claim 19 wherein the pattern in the seal material is in an area and to a depth which a blade will abrade when creating a seal.

21. Seal of Claim 20 wherein the depth of the pattern is within the range of about 0.01 to 0.1 inches.

22. Seal of Claim 20 wherein there is uncut seal material on two sides of the pattern.

23. Seal of Claim 14 wherein the pattern is selected from the group consisting of closely spaced holes, cross hatch, stripes and lines running perpendicular or parallel to the seal.

24. A gas turbine engine component comprising:

an abradable seal having a pattern cut into the surface of an abradable seal material with a laser effective to provide improved abradability in the area of the pattern.

25. Component of Claim 24 wherein the abradable seal material is a metallic alloy.

26. Seal of Claim 24 wherein the metallic alloy is selected from the group consisting of iron-based alloy, aluminum-based alloy, titanium-based alloy, nickel-based alloy, cobalt-based alloy, NiCr alloy, NiCrAl alloy and MCrAlY alloy where M is selected from the group consisting of Ni, Co or Fe.

27. Seal of Claim 26 wherein the abradable seal material contains non-metallic particles.

28. Seal of Claim 27 wherein the non-metallic particles are selected from the group consisting of boron nitride, bentonite, oxides, nitrides, borides, silicides, intermetallic compounds and plastics, polymers, and other organic compounds.

29. Seal of Claim 25 wherein the abradable seal material is in the form of a sheet attached to the gas turbine engine component.

30. Seal of Claim 25 wherein the abradable seal material is a thermal sprayed coating.

31. Seal of Claim 24 wherein the pattern is in an area and to a depth which a blade will abrade when creating a seal.

32. Seal of Claim 31 wherein the depth of the pattern is within the range of about 0.01 to 0.1 inches.

33. Seal of Claim 31 wherein there is uncut seal material on two sides of the pattern.

34. Seal of Claim 24 wherein the pattern is selected from the group consisting of closely spaced holes, cross hatch, stripes and lines running perpendicular or parallel to the seal.

FIG-1

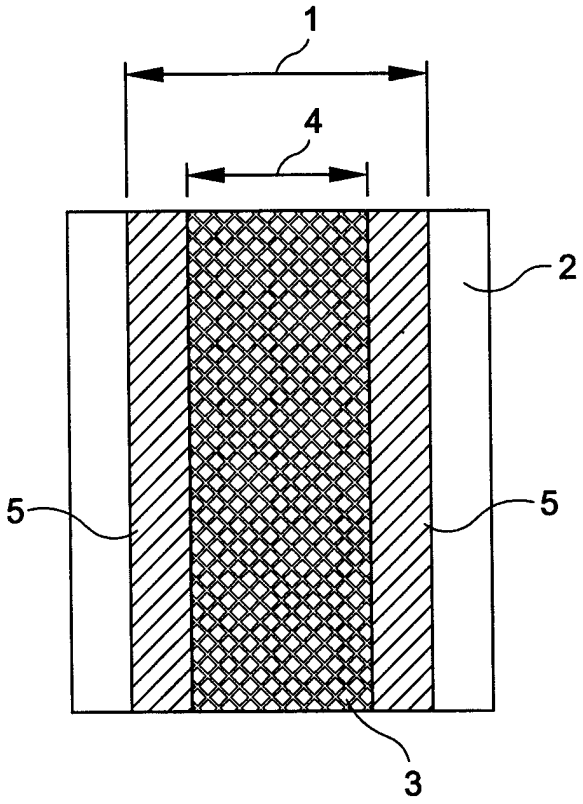


FIG-2

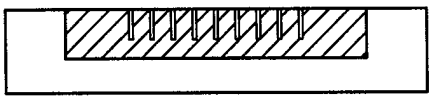


FIG-3

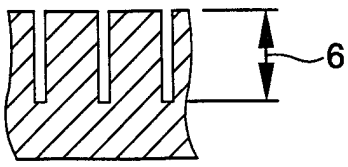


FIG-4

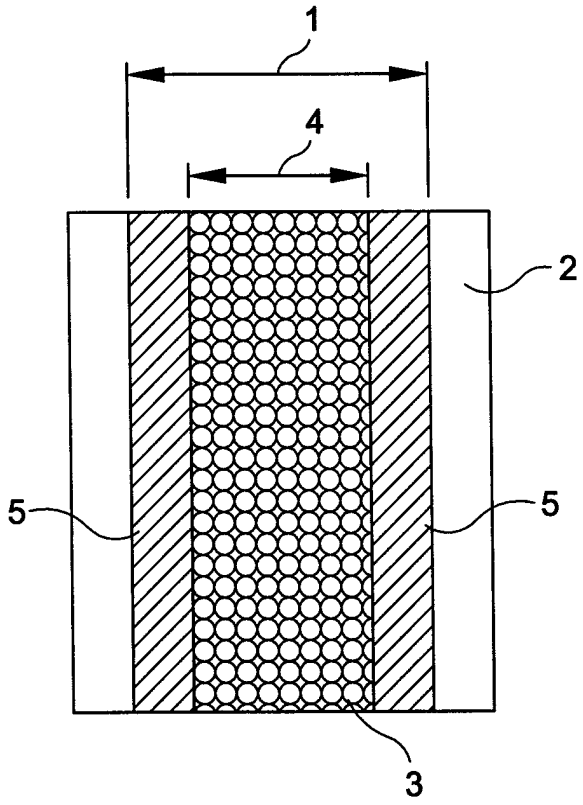


FIG-5

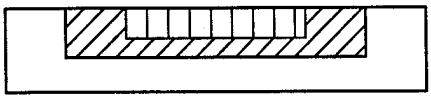


FIG-6

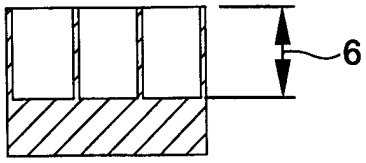


FIG-8

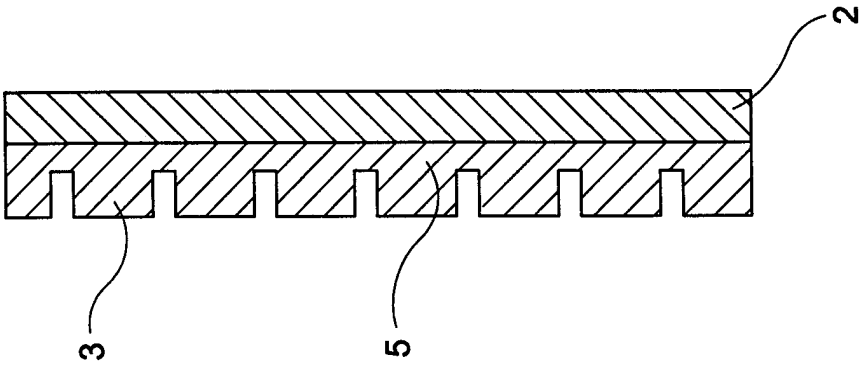


FIG-7

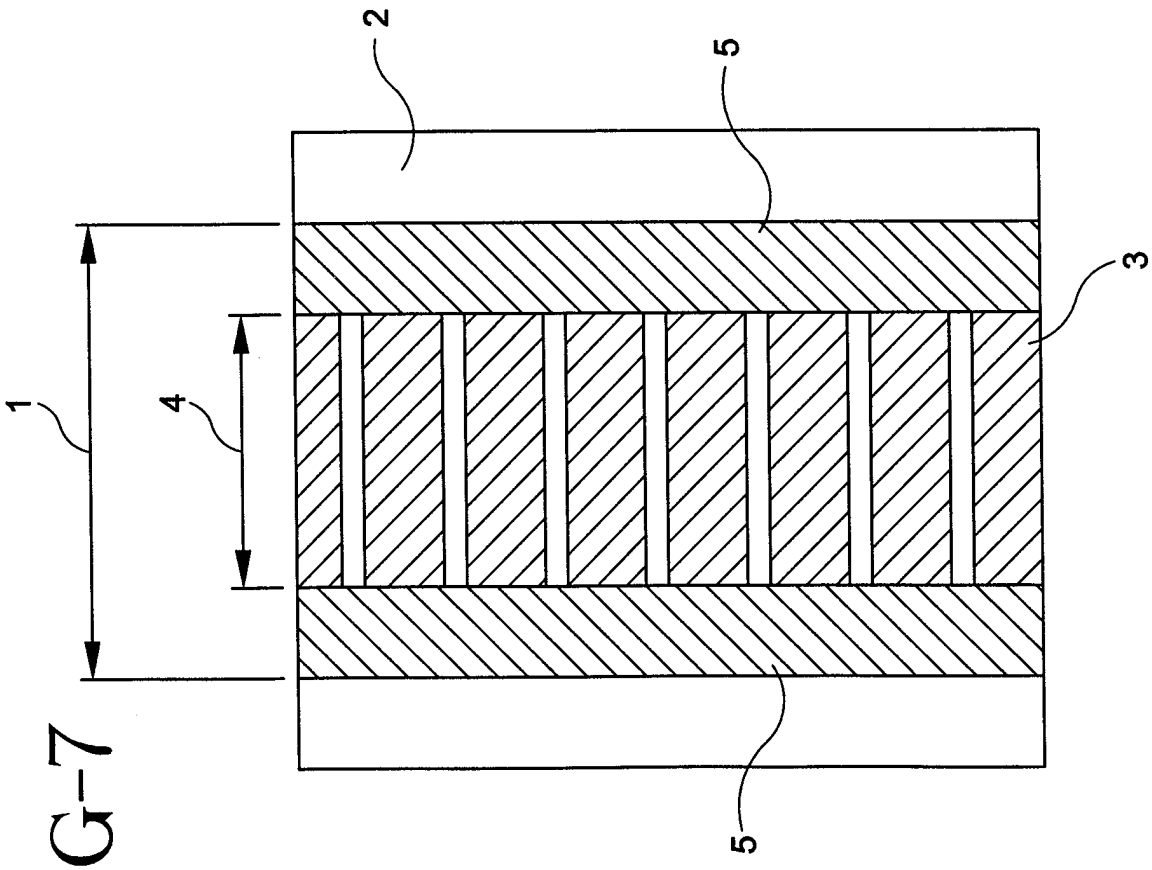


FIG-10

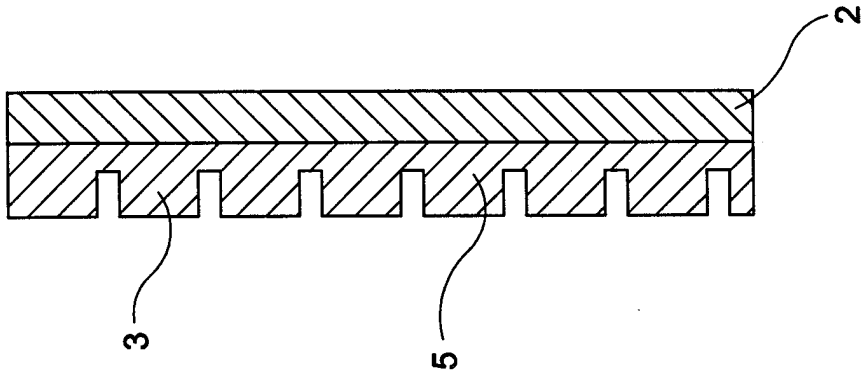


FIG-9

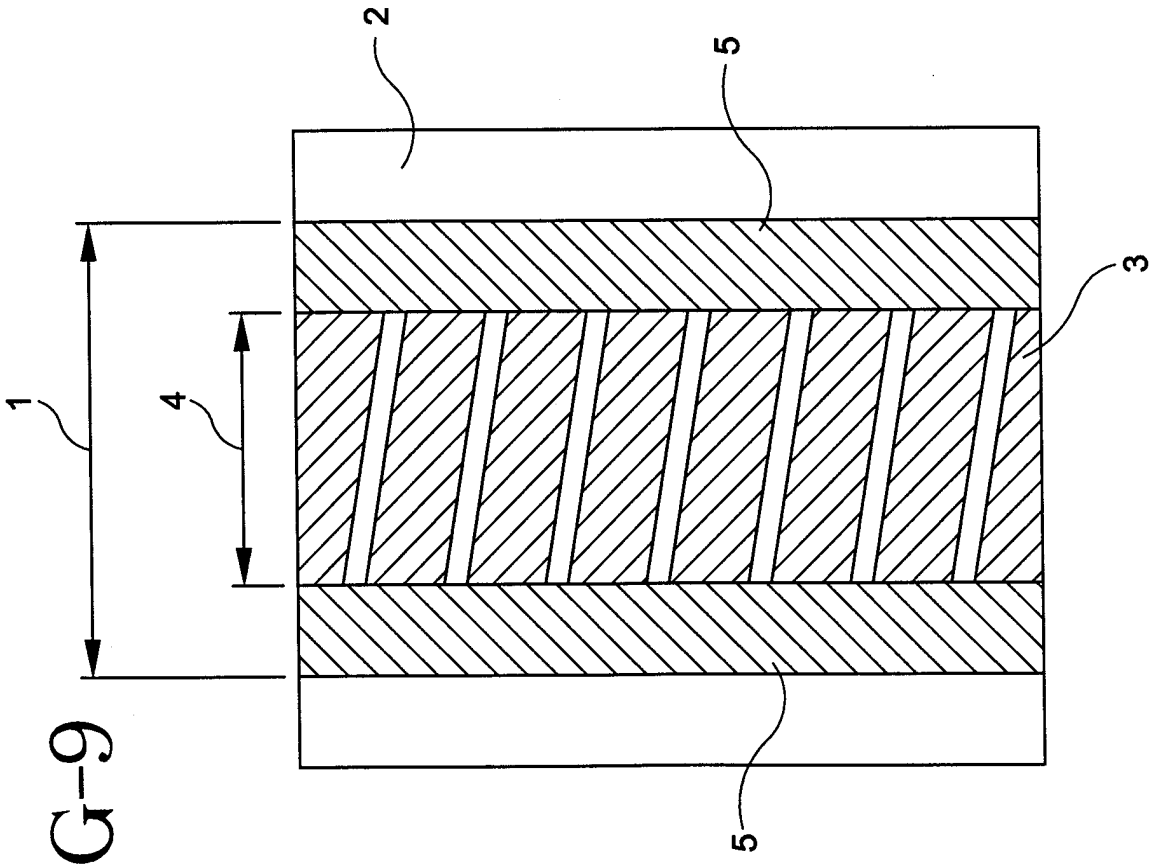


FIG-11

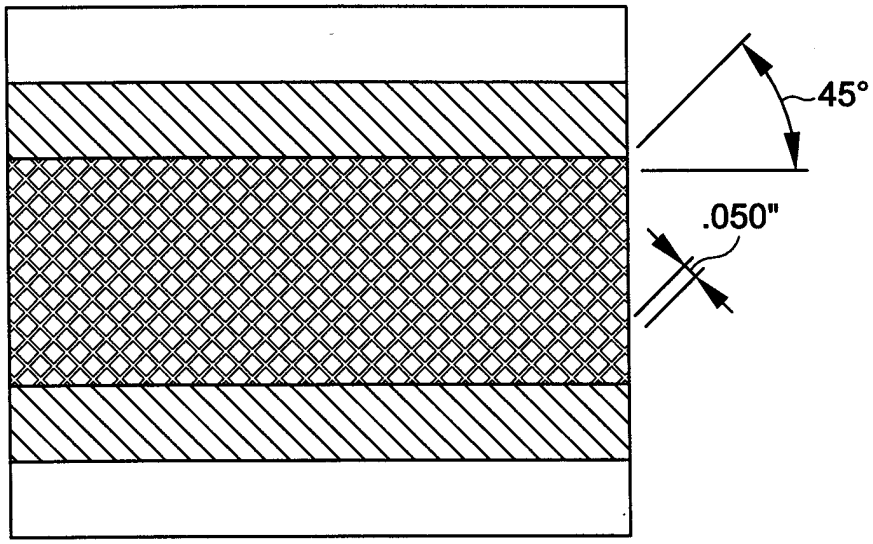
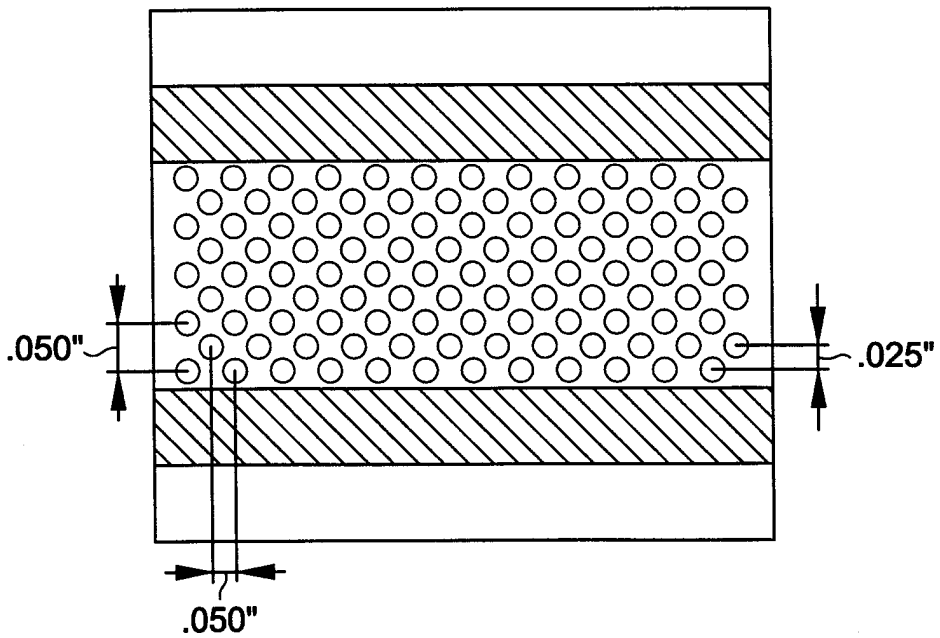


FIG-12



INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB97/01645

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :F01D 5/14; F04D 29/08; F16J 15/453; B23K 26/00, 26/02
US CL :148/194,196,197; 219/121.67, 121.68, 121.69; 277/415
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)

U.S. : 148/194,196,197; 219/121.67, 121.68, 121.69; 277/415

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 practicable, search terms used)

APS
search terms: laser, cutting or ablat####, abradable(1w)seal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,122,182 A (DORFMAN ET AL) 16 June 1992 (16-06-92), abstract, column 2, lines 53-column 3, line 32, examples.	4-13, 16-18, 25-30
Y	US 4,884,820 A (JACKSON ET AL) 05 December 1989 (05-12-89), abstract, figures 4 and 9, column 4, lines 50-column 5, line 5; column 6, lines 28-46; column 7, lines 60-68; column 8, lines 1-44.	1-34
Y	US 4,696,855 A (PETTIT, JR ET AL) 29 September 1987 (29-09-87), claim 5.	3-13, 16-18, 25-30
Y	US 4,374,173 A (ADAMOVIC) 15 February 1983 (15-02-83), abstract, column 4, lines 12-23, claims 12, 18-20.	3-13, 16-18, 25-30

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search 23 MARCH 1998	Date of mailing of the international search report 10 APR 1998
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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,262,206 A (RANGASWAMY ET AL) 16 November 1993 (16-11-93), abstract, column 7, line 7-column 8, line 50.	3-13, 16-18, 25-30