(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 September 2014 (25.09.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/151101 A1

(51) International Patent Classification:
F01D 5/14 (2006.01) *F02C 7/28* (2006.01)
F01D 5/20 (2006.01)

(21) International Application Number:
PCT/US2014/024983

(22) International Filing Date:
12 March 2014 (12.03.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/789,767 15 March 2013 (15.03.2013) US

(71) Applicant: **UNITED TECHNOLOGIES CORPORATION** [US/US]; One Financial Plaza, Hartford, Connecticut 06101 (US).

(72) Inventor: **STROCK, Christopher, W.**; 1 Portland Rd., Kennebunk, Maine 04043 (US).

(74) Agents: **CRAGGS, Brian, T.** et al.; 312 South Third Street, Minneapolis, Minnesota 55415 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

Published:
— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: TURBINE BLADE TIP TREATMENT FOR INDUSTRIAL GAS TURBINES

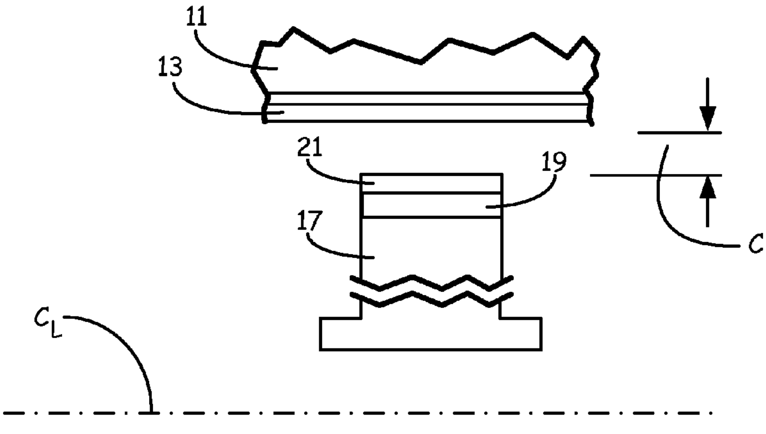

FIG. 2

(57) Abstract: A method of preventing transfer of metal of a gas turbine rotor blade having a metal tip to a blade outer air seal coating on a gas turbine case includes forming a coating on the metal tip. The coating comprises a bond coat layer on the metal tip and a ceramic filled metallic layer having a ceramic component in a matrix of a metal MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

WO 2014/151101 A1

TURBINE BLADE TIP TREATMENT FOR INDUSTRIAL GAS TURBINES

BACKGROUND

Large power generation turbines have a number of uses, such as driving a shaft to a generator or on the propeller of a large ship, for example. These turbines use thermal barrier coatings as blade outer air seal coatings in the hot section of the turbine. Due to the slow response rate of these large turbines, rub does not typically occur early in life like it does in aircraft engines.

When the rub does happen, it is at a slow interaction rate, high temperature and generally with high tip speeds. In this combination of conditions, the metal of the blade tips smears and galls to the ceramic blade outer air seal. This transferred material causes an increase in roughness on both the blade tips and outer air seal with associated aerodynamic looses and creates high spots on the outer air seals that then contact and remove material from, normally not contacting, blade tips resulting in an increased tip gap and a loss in performance.

These large power generation turbines will have better performance if metal transfer can be avoided.

SUMMARY

This invention prevents metal transfer to the ceramic blade outer air seal by applying a material to the blade tip that exhibits reduced material transfer to the blade outer air seals. The material includes a bond coat layer on the blade tip with a ceramic filled metallic layer on top of the bond coat layer. Ceramic is defined here to include the family of self-lubricating materials known as MAX phase materials.

The bond coat may be MCr, MCrAl., MCrAlY or a refractory modified MCrAlY, where M is nickel, cobalt, iron or mixtures thereof.

The blade tip coating contains ceramic particles in a matrix of MCr, MCrAl, MCrAlY or a refractory modified MCrA.Y where M is nickel, cobalt, iron or mixtures thereof.

The ceramic particles may be present in the coating with morphology retained from its manufacturing method or they may be irregularly flattened shapes that are described as “splats” in the thermal spray field. The ceramic particles may be any ceramic that has a hardness of seven or more on the Mohs Scale for hardness, such as silica, quartz, alumina and zirconia or may be a solid lubricant such as hexagonal boron nitride (hBN) or a MAX phase material. The hard particles act to limit metal buildup on the outer air seal by wholly or partially removing the transferred material while the self-lubricating filler interferes with adhesive metal transfer to the outer air seal.

The MAX phase materials are defined by the formula Mn+1AXn, where M is selected from the early transition metals. A is selected from A-group elements, X is selected from the group consisting of C or N and n= 1 to 3.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a simplified cross sectional view of a rotor shaft inside a casing illustrating the relationship of the blade outer air seal and rotors with tips.

FIG. 2 is a cross sectional view taken along the line 2-2 of FIG. 1, not to scale.

DETAILED DESCRIPTION

As can be seen from FIG. 1 and FIG. 2, a large turbine 10, generally, of the type used in connection with generators, for example, includes casing 11 with blade outer air seal coating 13. Power generators are one intended use of this invention and it is also contemplated for use with marine and land based turbines that may or may not have a fan or propeller. Turbine 10 also includes a shaft 15 with a plurality of blades 17 radiating from centerline C_L. Blades 17 have a first bond coat layer 19 on the tip of blades 17 and an abrasive layer 21 on bond coat layer 19. These layers may be applied by brazing a pressed and sintered layer or by thermal spraying.

Top ceramic filled metallic layer 21 is a composite of MCr, MCrAl, MCrAlY or a refractory modified MCrAlY, where M is nickel, cobalt, iron or mixtures thereof, into which ceramic particles have been added by thermal spraying. The metal alloy and ceramic may be deposited as a coating by individually feeding the powders to one or more spray torches or by blending the two powders and air plasma spraying (APS). Other spray processes would also be effective, such as combustion flame spray, HVOF, HVAF, LPPS, VPS, HVPS and the like. As part of the coating is a quantity of ceramic particles, the ceramic particles may be captured in the coating as unmelted inclusions retaining their original particle morphology or may at least partially melt during the spray process to form disc like flat particles, or splat particles.

The hard ceramic particles may be any ceramic that has a hardness of seven or more on the Mohs Scale for hardness, such as silica, quartz, alumina and zirconia and that at least partially melts at the spray temperatures. The amount of ceramic in this coating ranges from about 1% to about 15% by volume. Porosity makes up from about 1% to about 10% by volume, with the remainder being metal alloy.

Alternatively, a self-lubricating filler may be added in place of the hard ceramic particles. The amount of self-lubricating filler in coating 21 ranges from about 1% to about 50% by volume. Porosity makes up from about 1% to 10% by volume with the remainder being metal alloy.

In a third alternate combination, both hard ceramic particles and slelf-lubricating filler are added to the metal matrix. The amount of ceramic hard particles makes up about 1% to 15% by volume with a minimum of 40% by volume metal matrix and self-lubricating filler being the balance.

Attachment of the ceramic filled layer 21 to the airfoil 17 may be enhanced by including a bond coat layer on the airfoil tip. The bond coat may be MCr, MCrAl, MCrAlY or a refractory modified MCrAlY, where M is nickel, cobalt, iron or mixtures thereof.

Bond coat 19 is thin, up to 10 mils (254 microns), more specifically ranging from about 3 mils to about 7 mils (about 76 to about 178 microns). The ceramic filled metallic coating 21 may be about the same thickness as bond coat 64, again ranging from about 3 mils to about 7 mils (about 76 to about 178 microns), while some applications that have larger variation in tip clearance may require a thicker ceramic filled layer. Layer 21 may be as thick as 300 mils (7620 microns) in some applications.

FIG. 2 shows blade 17, partially cut away, with bond layer 19 and abrasive layer 21, not to scale. Clearance C is expanded for purposes of illustration. In practice, clearance C may be, for example, in a range of about 0.025 inches (0.06125 cm) to 0.055 inches (0.1397 cm) when the engine is cold and 0.000 to 0.035 inches (0.0 to 0.0889 cm) during engine operation, depending on the specific operating conditions and previous rub events that may have occurred.

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

DISCUSSION OF POSSIBLE EMBODIMENTS

The following are nonexclusive descriptions of possible embodiments of the present invention.

A method of preventing transfer of metal of a gas turbine rotor blade having a metal tip to a blade outer air seal coating. A coating on the blade tip of a ceramic filled metallic layer having a ceramic component in a matrix of MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

The method of the preceding paragraph can optionally include additionally and/or alternatively, any one or more of the following features, configurations and/or additional components.

The method may include having a bond coat layer on the metal tip.

The ceramic component has a hardness of seven or more on the Mohs Scale.

The ceramic component can be selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof.

The metal may be selected from the group consisting of nickel, cobalt, copper, iron, aluminum and mixtures thereof.

The ceramic component may be selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof and the metal may be selected from the group consisting of MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

A rotor and blade seal coating preventing transfer of metal of a gas turbine rotor blade having a metal tip to a blade outer air seal coating. A coating on the blade tip comprises a ceramic filled metallic layer having a ceramic component in a matrix of MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

The rotor and blade seal coating of the preceding paragraph can optionally include additionally and/or alternatively, any one or more of the following features, configurations and/or additional components.

The ceramic component has a hardness of seven or more on the Mohs Scale.

The ceramic component can be selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof.

The metal may be selected from the group consisting of nickel, cobalt, copper, iron, aluminum and mixtures thereof.

The amount of nickel, cobalt, copper, iron or aluminum may range from about 30% to about 60% by volume, and the balance is hBN.

The ceramic component may be selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof and the metal is MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof..

A gas turbine engine having a plurality of rotor blades having a metal tip and a blade outer air seal coating A coating on the blade tip includes a ceramic filled metallic layer having a ceramic component in a matrix of MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

The gas turbine engine having a plurality of rotor blades having a metal tip and a blade outer air seal coating of the preceding paragraph can optionally include additionally and/or alternatively, any one or more of the following features, configurations and/or additional components.

The engine may have a bond coat on the metal tip.

The ceramic component has a hardness of seven or more on the Mohs Scale.

The ceramic component can be selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof.

The metal may be selected from the group consisting of nickel, cobalt, copper, iron, aluminum and mixtures thereof.

The ceramic component may be selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof and the metal may be selected from MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

CLAIMS:

1. A method of preventing transfer of metal of a gas turbine rotor blade having a metal tip to a blade outer air seal coating, comprising:

a blade outer air seal coating on a gas turbine case; and

a coating on the metal tip, the coating comprising a ceramic filled metallic layer having a ceramic component in a matrix of a metal.

2. The method of claim 1, wherein the ceramic component has a hardness of seven or more on the Mohs Scale.

3. The method of claim 2, wherein the ceramic component is selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof.

4. The method of claim 1, wherein the metal is selected from the group consisting MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

5. The method of claim 1, which further includes a bond coat on the metal tip between the metal tip and the ceramic filled metallic layer.

6. The method of claim 1, wherein the ceramic component is selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof and the metal is selected from the group consisting of MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

7. A rotor and blade seal coating preventing transfer of metal of a gas turbine rotor blade having a metal tip to a blade outer air seal coating, comprising:

a blade outer air seal coating on a gas turbine case; and

a coating on the metal tip, the coating comprising a ceramic filled metallic layer having a ceramic component in a matrix of a metal.

8. The rotor and blade seal coating of claim 7, wherein the ceramic component has a hardness of seven or more on the Mohs Scale.

9. The rotor and blade seal coating of claim 8, wherein the ceramic component is selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof.

10. The rotor and blade seal coating of claim 7, wherein the metal is selected from the group consisting of nickel, cobalt, copper, iron, aluminum and mixtures thereof.

11. The rotor and blade seal coating of claim 7 which further include a bond coat on the metal tip between the metal tip and the ceramic filled metallic layer.

12. The rotor and blade seal coating of claim 7, wherein the ceramic component is selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof and the metal is selected from the group consisting of MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

13. In a gas turbine engine having a plurality of rotor blades having a metal tip and a blade outer air seal coating, comprising:

a blade outer air seal coating on a gas turbine case; and

a coating on the metal tip, the coating comprising a ceramic filled metallic layer

14. The gas turbine engine of claim 13, wherein the ceramic component has a hardness of seven or more on the Mohs Scale.

15. The gas turbine engine of claim 14, wherein the ceramic component is selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof.

16. The gas turbine engine of claim 13, wherein the metal is selected from the group consisting of nickel, cobalt, copper, iron, aluminum and mixtures thereof.

17. The gas turbine engine of claim 16, which further includes a bond coat on the metal tip, the bond coat being between the metal tip and the ceramic filled metallic layer.

18. The gas turbine engine of claim 13, wherein the ceramic component is selected from the group consisting of silica, quartz, alumina, zirconia and mixtures thereof and the metal is selected from the group consisting of MCr, MCrAl, MCrAlY or a refractory modified MCrAlY where M is nickel, cobalt, iron or mixtures thereof.

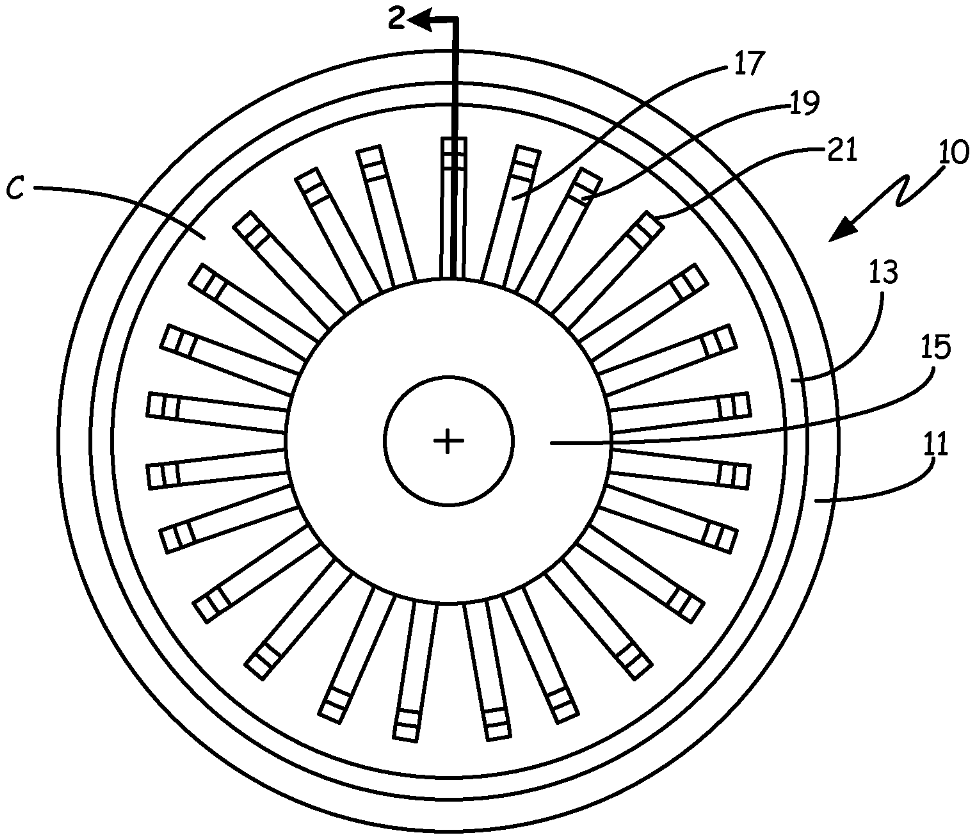

FIG. 1

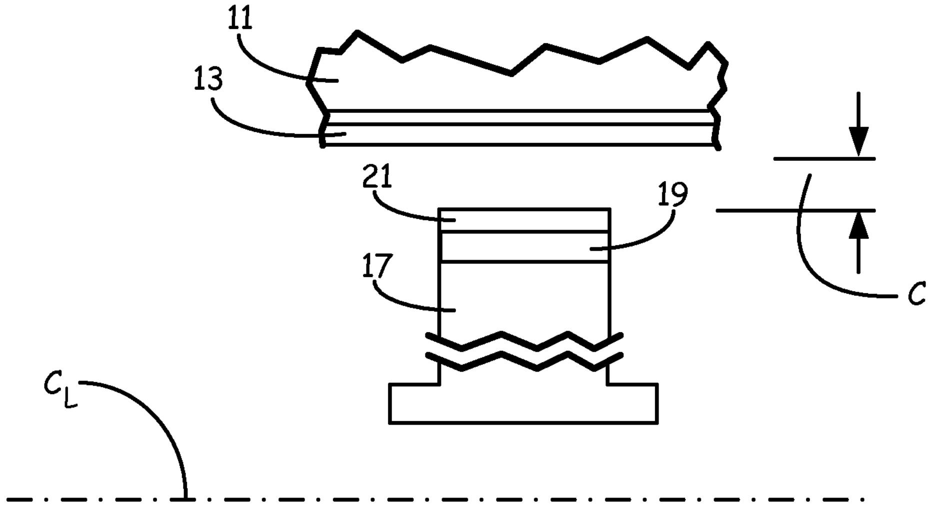

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/024983

A. CLASSIFICATION OF SUBJECT MATTER

F01D 5/14(2006.01)i, F01D 5/20(2006.01)i, F02C 7/28(2006.01)i

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)
F01D 5/14; B05D 3/02; B32B 15/04; B05D 7/00; B05D 1/38; B21D 39/00; B64C 11/00; B22D 25/00; C03C 27/02; B64C 27/00; F01D 5/20; F02C 7/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: turbine engine, blade tip, seal, ceramic, metal, smear, gall, rub, and coating

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0173094 A1 (MANIER et al.) 08 July 2010 See abstract; paragraphs [0020],[0021],[0024],[0026]; and figures 1-3.	1-18
Y	US 5,059,095 A (KUSHNER et al.) 22 October 1991 See abstract; column 3, lines 3-19, column 4, lines 42-52; and figures 1-3.	1-18
A	US 2007-0099011 A1 (WILSON, SCOTT) 03 May 2007 See abstract; paragraphs [0033],[0036]-[0039],[0043],[0051]; and figures 1-4.	1-18
A	US 5,952,110 A (SCHELL et al.) 14 September 1999 See abstract; column 4, lines 4-18,28-31; and figure 1.	1-18
A	US 6,102,656 A (NISSLEY et al.) 15 August 2000 See abstract; column 2, line 55 - column 3, line 16; and figures 1,2.	1-18

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 July 2014 (17.07.2014)	**17 July 2014 (17.07.2014)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
HAN, Joong Sub
Telephone No. +82-42-481-5606

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0173094 A1	08/07/2010	AT 524576 T	15/09/2011
		CA 2679517 A1	13/11/2008
		CA 2679517 C	11/02/2014
		EP 2171124 A1	07/04/2010
		EP 2171124 B1	14/09/2011
		JP 04910096 B2	04/04/2012
		JP 2010-526232 A	29/07/2010
		KR 10-1372342 B1	12/03/2014
		KR 10-2010-0018500 A	17/02/2010
		WO 2008-135803 A1	13/11/2008
US 5059095 A	22/10/1991	None	
US 2007-0099011 A1	03/05/2007	AT 491052 T	15/12/2010
		CA 2550535 A1	14/01/2007
		CA 2550535 C	08/04/2014
		CN 1896464 A	17/01/2007
		CN 1896464 B	18/04/2012
		DE 502006008460 D1	20/01/2011
		EP 1743957 A1	17/01/2007
		EP 1743958 A1	17/01/2007
		EP 1743958 B1	08/12/2010
		ES 2355152 T3	23/03/2011
		JP 04799302 B2	26/10/2011
		JP 2007-024042 A	01/02/2007
		RU 2006125253 A	20/01/2008
		RU 2414547 C2	20/03/2011
		US 7718280 B2	18/05/2010
US 5952110 A	14/09/1999	None	
US 6102656 A	15/08/2000	DE 69611138 D1	11/01/2001
		DE 69611138 T2	19/07/2001
		EP 0765951 A2	02/04/1997
		EP 0765951 A3	14/05/1997
		EP 0765951 B1	06/12/2000
		ES 2153941 T3	16/03/2001
		JP 04004577 B2	07/11/2007
		JP 09-133006 A	20/05/1997
		US 5705231 A	06/01/1998
		US 5780171 A	14/07/1998