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(74) Agents: SOLOWAY, Norman, P. et al.; Hayes Soloway  
P.C., 3450 E. Sunrise Drive, Suite 140, Tucson, Arizona  
85718 (US).

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(71) Applicant (for all designated States except US): MA-  
TERIALS & ELECTROCHEMICAL RESEARCH  
CORP. [US/US]; 7960 South Kolb Road, Tucson, Arizona  
85706 (US).

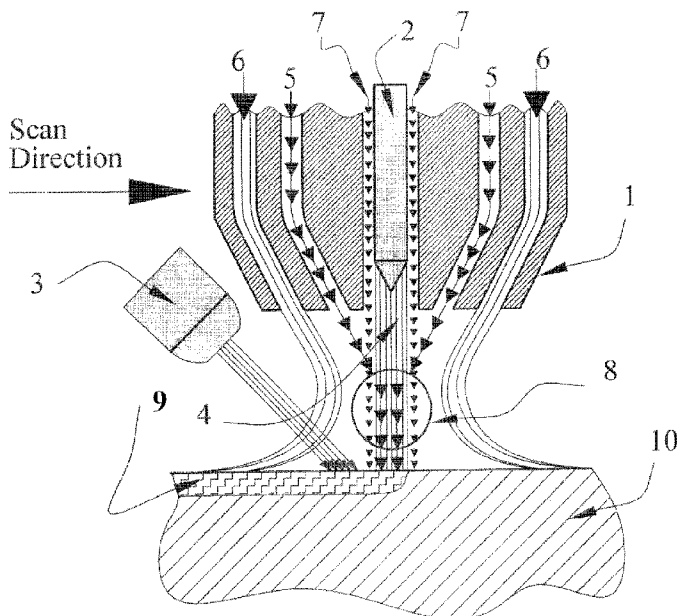
(72) Inventors; and

(75) Inventors/Applicants (for US only): STORM, Roger,  
S. [US/US]; 4421 N. Palisade Drive, Tucson, Arizona  
85749 (US). SHAPOVALOV, Vladimir [US/US]; 12532  
Prospect Avenue, Albuquerque, New Mexico 87112 (US).  
WITHERS, James, C. [US/US]; 6594 E. Celsius Place,  
Tucson, Arizona 85750 (US). LOUTFY, Raouf [US/US];  
6507 N. Ventana Canyon, Tucson, Arizona 85715 (US).

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(54) Title: METHOD OF USING A THERMAL PLASMA TO PRODUCE A FUNCTIONALLY GRADED COMPOSITE SUR-  
FACE LAYER ON METALS



(57) Abstract: A method of material treatment in which the surface of a metal substrate is converted to a composite structure of the metal and its nitride or carbide utilizing a high temperature chemically active thermal plasma stream, and the product obtained from that method. The complex thermal plasma contains controllable additions of active gas, liquid or solid substances. The surface layer obtained is functionally graded to the substrate resulting in an excellent bond that resists delamination and spalling, and provides a significant increase in hardness, wear and erosion resistance, and corrosion resistance, and a decrease in coefficient of friction.

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**INTERNATIONAL SEARCH REPORT**

International application No.  
PCT/US 07/66812

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC(8) - H05H 1/26; C23C 8/24; C22F 1/16 (2008.01)  
 USPC - 427/576; 148/210, 669  
 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)  
 IPC(8): H05H 1/26; C23C 8/24; C22F 1/16 (2008.01)  
 USPC: 427/576; 148/210, 669

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
 All Prior Art Databases (text search ? see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
 PubWEST (PGPB,USPT,USOC,EPAB,JPAB); DialogPro (Engineering); Google Scholar; Google Patents; FreePatentsOnline  
 Search Terms: atm, bond, carbide, carbon black, coat?, delamination, gradient, hardness, ion, James Withers, me8\$4, metal, MPa, nbrid\$3, phase, plasma, power, Raouf Loufy, Rockwell C, Roger Storm, spalling, stren

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,411,960 A (MIZUHARA) 25 October 1983 (25.10.1983), entire document especially col. 1, ln. 63 - col. 2, ln. 8 and col. 2, ln. 57-66	28-32
Y		33-44
Y	EP 1319733 A2 (RICHARDSON) 18 June 2003 (18.06.2003), para [0001], [0005], [0011], [0014], [0058], [0077], [0082]	33-44
Y	US 5,830,540 A (BOWERS) 03 November 1998 (03.11.1998), entire document especially FIG. 2, col. 2, ln. 50-53, col. 2, ln. 56 ? col. 3, ln. 17, col. 3, ln. 32-42, col. 4, ln. 13-35, col. 4, ln. 47-56, col. 5, ln. 32-37	1-27 and 39-44
Y	US 5,062,900 A (BERNERON et al.) 05 November 1991 (05.11.1991) col. 1, ln. 6-12, col. 1, ln. 41-57, col. 2, ln. 37-60	1-19
Y	US 5,306,531 A (LAURENCE et al.) 26 April 1994 (26.04.1994) col. 12, ln. 61-64	7-8, 16-19
Y	US 5,679,167 A (MUEHLBERGER) 21 October 1997 (21.10.1997), col. 4, ln. 2-5, col. 10, ln. 1-35	10 and 21
Y	EP 1340837 A1 (VAN ENCKEVORT) 03 September 2003 (03.09.2003) para [0043], [0044]	20-27
Y	US 2003/0233977 A1 (NARENDAR et al.) 25 December 2003 (25.12.2003) para [0027]	43-44

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search 14 February 2008 (14.02.2008)	Date of mailing of the international search report <b>27 MAR 2008</b>
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Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: <i>B. Handorf</i> Lee W. Young PCT Helpdesk 571-272-4300 PCT OSP: 571-272-7774
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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 07/66812

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

Group I: Claims 1-27, directed to a method of using a direct arc plasma with a gaseous reactant to produce a surface layer on an electrically conductive piece.

Group II: Claims 28-44, directed to a structure comprising titanium having a surface layer with a high ceramic content that is functionally graded to the titanium or titanium alloy substrate.

The Searching Authority finds that the present application lacks unity, and contains two separate inventions as delineated by the above groups in view of US 2004/0023048 A1 to Schwartz et al. of 5 February 2004. Schwartz teaches a titanium material functionally graded (para [0006]) to a ceramic (claim 8). Further, Group II is not specifically directed to a material treated according to the method of Group I. As such, the above groups do not share a common innovative technical element. Groups I and II thus lack unity of invention under PCT Rule 13 because they do not share a same or corresponding special technical feature.

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.