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(54) Spark plug or igniter electrodes and spark plugs or igniters embodying same.

(57) A spark plug or other spark igniter is provided in which at least an operative part of one, both or all electrodes thereof is made of a material including an intermetallic compound having a melting point above 1400°C and chosen to exhibit adequate toughness, resistance to thermal shock, and electrical conductivity. The intermetallic compound may form one phase of a multi-phase material. Ruthenium aluminide is disclosed as a preferred intermetallic compound.

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FIELD OF THE INVENTION

THIS INVENTION relates to spark plug or igniter electrodes, including both positive and negative electrodes, tips or inserts for such electrodes, and spark plugs and igniters embodying same. The spark plugs may be of the general nature employed in internal combustion engines for effecting ignition thereof. An igniter may be of the general type for use in turbine engines.

BACKGROUND TO THE INVENTION

Trends in modern high performance engines have resulted in more exact performance requirements.

There is a trend towards long-life spark plugs. Furthermore, the introduction of unleaded fuels is enabling spark plug manufacturers to use different and new materials.

Accordingly, the longevity of spark plugs, in particular the electrodes thereof, is of increasing importance in view of the increased demands thereon.

This invention seeks to provide inserts or tips for spark plug electrodes, spark plug electrodes and spark plugs embodying same, in which the electrodes are able to stand up to the rigorous use made of them.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided a spark plug or igniter electrode characterised in that the electrode, or a tip or insert mounted onto or into the electrode, is made at least predominantly of one or more intermetallic compounds having a melting point above 1400°C and wherein the intermetallic compound or compounds is or are chosen to exhibit adequate toughness, resistance to thermal shock, and electrical conductivity.

It is to be understood that in this specification the term "tip" is to be interpreted as including a pad, layer, or any other separate element secured to an electrode. Such a tip is preferably bonded, such as to a nickel or nickel alloy electrode part, by diffusion welding or the like.

Preferred features of the invention provide for the intermetallic compound or compounds to be selected from the groups comprising ruthenium and aluminium (herein referred to as ruthenium aluminide); ruthenium, aluminium and nickel; platinum and aluminium; ruthenium and titanium; nickel and aluminium; titanium and aluminium; ruthenium and zirconium; ruthenium and tantalum; iron and aluminium; niobium (columbium) and aluminium; molybdenum and silicon; iridium and niobium; iridium and hafnium; iridium and titanium; iridium and tantalum; and for the intermetallic material optionally to be dispersed in one or more other phases thereby forming a dual- or multi-phase material.

The intermetallic compounds are solid-state intermediate phases in alloy systems, generally formed between chemically dissimilar metals. They often have relatively simple stoichiometric proportions and often have narrow composition ranges of homogeneity (or even a fixed composition). The nature of atomic bonding may vary from metallic to ionic. They are often believed to have essentially nonmetallic properties such as poor electrical conductivity (S.H. Avner, *Introduction to Physical Metallurgy*, McGraw-Hill Second Edition, p.149). They have long been known to have high melting points and good oxidation resistance.

However, the perception that they show poor ductility and other "non-metallic" properties has prevented intermetallic compounds from being widely used as general engineering materials. Some intermetallic compounds are well researched materials today, and have found a number of applications - however, they have not yet been implemented on the scale envisaged, particularly in high-temperature gas turbines. Care should accordingly be exercised in selecting the intermetallic compound or compounds to be used in implementing the invention.

The particular advantage of ruthenium aluminide (the presently preferred intermetallic compound) and some other intermetallic compounds is that they exhibit significant toughness at room temperature; have a high melting point; good oxidation resistance; and, outstanding corrosion resistance. The thermo-dynamic stability that these materials exhibit at elevated temperatures and in an aggressive medium is therefore paramount. It has also been demonstrated that these compounds exhibit adequate electrical and thermal conductivity as well as adequate resistance to thermal fatigue.

Of particular interest are dual or multi phase materials comprising ruthenium aluminide, in an excess of ruthenium; preferably containing between 80 and 99 mass percent Ru; and most preferably about 90 mass percent Ru.

Some intermetallic compounds such as ruthenium aluminide are, however, difficult to manufacture by conventional techniques such as melting and casting, in view of their very high melting points (approximately 2050°C for ruthenium aluminide); the aggressive attack of ruthenium aluminide and other intermetallics on refractories in the molten state; and, the volatilisation of aluminium consequent on the high temperature.

However, applicant has devised a number of processes for the manufacture of such intermetallic compounds and one such process forms the subject matter of applicant's South African Patent No. 94/3636 entitled "The Manufacture of Ordered Intermetallic Compounds".

In that patent we describe a process for the production of intermetallic precious metal aluminide compounds wherein the required metal, in powdered form, is intimately mixed with powdered aluminium in the required relative quantities, generally based, at least to a large extent, on the stoichiometric atomic ratios of the precious metal and aluminium in the intermetallic product. The intimately mixed powders are formed into a shaped body using any necessary optional steps such as de-gassing, and in particular, encapsulating such as in tantalum or molybdenum foil and a titanium can, followed by heating under pressure to effect reactive hot isostatic pressing followed by any required homogenisation at elevated temperature.

In the case of ruthenium aluminide, which is the material chosen for further testing, the aluminium powder particle size range was between 22 and 72 μm and that of the precious metal was from 13 to 58 μm on average. The preferred powder size was about 22 μm in the case of aluminium and about 13μm in the case of the precious metal. The compaction pressure is preferably chosen from the range between 415 and 750 MPa and preheating at a temperature of about 500°C is preferably carried out preparatory to sintering at a temperature of about 1600°C for a period of about 12 hours.

A number of other manufacturing processes can be used without deviating from the scope of this invention. These include, but are not limited to, a variety of melting processes, forming processes, and a variety of powder metallurgy processes such as sintering and metal spraying processes. Material may also be produced by any combination of the above processes without deviating from the scope hereof.

The invention also provides a spark plug or other igniter embodying one or more electrodes as defined above. Whilst usually both or all of the electrodes will be made according to the invention, it may be that only one, for example the central electrode, employs an intermetallic compound. The spark plugs may be utilised in engines operating on leaded or unleaded fuels. Although ruthenium aluminide, with compositions close to 50 atomic per cent Ru, is attacked by leaded fuels, ruthenium-rich ruthenium aluminide may be utilised in engines operating on leaded fuels.

In order that the invention may be more fully understood a detailed description of preferred embodiments is given below. In this description reference is made to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:-

Figure 1	is an elevation of an experimental spark plug to which the invention is applied;
Figure 2	is an enlarged elevation of the electrode end of the experimental spark plug with a modified central electrode fitted with an insert of intermetallic material; and,
Figure 3	is a view similar to Figure 2 but showing the standard shape of central electrode.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION WITH REFERENCE TO THE DRAWINGS

It has been found that certain intermetallic compounds exhibit relatively high electrical and thermal conductivity. For example, as indicated in Table 1 the electrical resistivity of ruthenium aluminide compares favourably with those of previous metals used commercially in spark plug electrodes viz. platinum and gold-50-mass%-palladium. Electrical resistivity of three ruthenium aluminide materials, viz. 52 atomic per cent Ru and 48 atomic per cent Al (80,23 mass % Ru) (Ru52Al48); 48 atomic per cent Ru and 52 atomic per cent Al (77,57 mass % Ru) (Ru48Al52); and, 70 atomic per cent Ru and 30 atomic per cent Al (90 mass % Ru) ($Ru_{70}Al_{30}$) was measured as well as those of Pt and of Au-Pd alloy. Values for the resistivity of Pt from the literature are also given.

TABLE 1

Electrical resistivity of previous metals and ruthenium aluminide compounds as a function of temperature. (Resistivity given in ohm-cm)

TEMPE-RATURE (C)	Pt(exp) Experimental alloy	Pt(lit) Values from literature	Au-Pd(exp) Experimental alloy (note 1)	Ru48A152	Ru52A148	Ru70Al30
20		10,6	27,7			
20	11,1					23,2
21	11,6					
24				15,1		23,8
35				15,7		
90	13,4				24,1	
98	13,9					26,2
100	14,0					
102		13,6	28,6	17,3	26,1	
109	14,1			17,6		
125						27,4
184	17,6					
193	17,7					
200	18,0			21,1		
204						29,7
211						30,3
281	21,3		29,8		29,8	
294	21,5					
300	21,5		30,4	25,0	33,5	
302	21,7			25,1		
306						33,5
386	24,7					
390						35,8
398						36,3
400	25,5		31,9	28,8	37,0	
401				29,3		
500	28,9	27,9	32,6		40,4	
502	29,0			33,0		39,9
531						41,5
600	31,6		33,4			
601						42,9
700	34,5					46,0
706						47,3
710	35,4					
798						49,3
800	37,3					
895						52,7
900	40,3					
1000	43,1	43,1				
1013						57,3

Also the thermal conductivity of NiAl has been reported to be higher than that of some nickel-based superalloys. It is known that a correlation exists between thermal conductivities and electrical conductivities of metallic materials.

It should therefore be clear that both electrical conductivity and thermal conductivity of certain intermetallic compounds, and specifically those of ruthenium aluminide, are sufficient to allow these materials to be used as spark plug or igniter electrodes, provided that the melting point of such intermetallic compound exceeds 1400°C.

EXPERIMENTAL TRIALS

The functionality of intermetallic compounds for use in spark-plug electrodes was tested as follows:-

Experimental material was prepared by one of two routes, namely:

(i) by arc melting, and

(ii) by reactive hot isostatic pressing of the constituent elements as described above and in our said South African Patent No. 94/3636 and outlined above.

A number of different compositions of experimental ruthenium aluminide materials were manufactured and tested in a number of experiments.

In each case an experimental electrode insert 1 of 1mm in diameter for centre (negative) electrode 2 of a spark plug 3 was machined from the respective experimental material to the required geometry. The electrode inserts were incorporated into standard spark plug configurations as centre electrodes only, whereby each experimental electrode insert was held within a nickel socket, and was contacted to the nickel by cold deforming.

Experimental trials comprised the following:

(i) Evaluation of spark intensity

Mounting of the spark plugs in an ignition system test-bed, whereupon sparking was induced by the application of voltage, as with conventional ignition systems utilised in spark ignited engines. The sparking behaviour was observed, and compared with that of standard spark plugs.

Relative to standard spark plugs, the spark intensity of the experimental spark plugs was similar. Transfer of the spark took place from the experimental electrode material and not from the surrounding nickel jacket, confirming sufficient electrical conductivity of the ruthenium aluminide.

(ii) Evaluation of performance utilising leaded fuel

The following experimental ruthenium aluminide alloys were manufactured by arc melting:-

1. slightly rich in aluminium
2. stoichiometric in ruthenium and aluminium, based on an atomic ratio of 50:50, and
3. slightly rich in ruthenium.

The lengths of the ruthenium aluminide electrode inserts were varied slightly for comparative purposes.

The spark plugs were mounted in a standard six-cylinder internal combustion engine, connected to a dynamometer capable of maintaining the engine at a constant speed, with parameters such as torque, power, engine coolant temperature, and fuel consumption being directly measurable. The performance was subsequently determined under full- and partial axle loading at speeds up to 5000 revolutions per minute. Testing was carried out using leaded fuel consistent with an octane rating of 93.

The performance of the electrodes was further evaluated by microstructural analysis of the working tip. Wear characteristics were monitored by means of computerised profile scanning on a Mitutoyo Scanpak-3 V2.10.

These experiments yielded the following observations in respect of ruthenium aluminide having a 50:50 atomic ratio:

1. The experimental materials yielded comparable fuel consumption, torque, and power to the standard spark plugs under identical operating conditions. The results showed a variation in performance between the experimental and standard commercial spark plugs (reference nickel electrodes) of less than 2%.
2. No ignition difficulties were encountered during hot or cold start-ups of the experimental spark plugs.
3. The experimental spark plugs were not associated with any uneven or irregular running or knocking of the engine.
4. The experimental spark plugs were not associated with "run-on" after the engine had been switched off while running at high speeds, caused by self-ignition due to an excessively hot electrode.
5. The experimental-electrodes proved to have a high resistance to the thermal shock and mechanical vibration encountered, and that none of the electrodes failed during testing.
6. The wear-performance of the experimental electrodes can be modified by changing, amongst other things, the electrode length, and the design of the spark plug configuration.

7. Solid-state welding had taken place between the experimental electrode inserts and the nickel sheath, demonstrating that the experimental material can be successfully bonded to nickel.
8. Ruthenium aluminide of this particular composition is subject to chemical attack by the tetraethyl lead component in leaded fuels.

(iii) Evaluation of electrode erosion utilising leaded fuel and Ru-rich ruthenium aluminide material that had been manufactured by arc melting

As in prior art it is known that ruthenium is resistant to attack by the tetra-ethyl lead component in fuels, centre electrode inserts were manufactured from the following ruthenium-rich dual-phase ruthenium-aluminide alloys:

1. 60.2 atomic per cent Ru and 39.8 atomic percent Al,
2. 70.61 atomic per cent Ru and 29.39 atomic per cent Al,
3. 85.53 atomic per cent Ru and 16.47 atomic per cent Al.

Spark plugs containing these electrode inserts were tested in a dynamometer-mounted engine that was run on leaded fuel at engine speeds up to 5 000 r/min at full open throttle and full load.

This experiment yielded the following results:

1. Performance of the spark plugs and the resulting engine performance was in all respects similar to results obtained by using standard commercial spark plugs (reference nickel electrodes).
2. Erosion rates of the centre electrodes were less than the erosion rates that could be expected of commercial nickel electrodes. This indicates that Ru-rich ruthenium aluminide may be utilised as a spark plug electrode material for use in fuels with a high lead content.
3. There exists an optimum composition for erosion resistance in the hypo-eutectic region between 80 and 95 mass per cent ruthenium for leaded fuels.
4. Solid-state welding had taken place between the experimental electrode inserts and the nickel sheath, demonstrating that the experimental material can be successfully bonded to nickel.

(iv) Evaluation of electrode erosion relative to the erosion of a commercial gold-palladium electrode, utilising unleaded fuel and material manufactured by hot isostatic pressing

Centre electrode inserts as described above were manufactured from the following ruthenium aluminide materials that had been manufactured by hot isostatic pressing:

TABLE 2

Ru PER CENT		Al PER CENT		PER CENT BORON	
ATOMIC	MASS	ATOMIC	MASS	ATOMIC	MASS
50	(78,93)	50	(21,07)	0	0
53	(80,86)	47	(19,14)	0	0
52,735	(80,79	46,765	(19,13)	0,5	(0,08)

The electrode configuration was similar to that of a standard commercial spark plug which has a gold-palladium electrode tip.

Spark plugs containing the experimental ruthenium aluminide centre electrodes were tested in two experiments (40 and 48 hours respectively) to compare erosion rates. The tests were conducted at full load and at engine speeds between 3500 and 5500 r/min.

These experiments indicated that:-

1. Erosion rates of the ruthenium aluminide materials was similar to and in some cases better than that of the gold-palladium material in unleaded fuels.
2. The alloy with 53 atomic per cent ruthenium exhibited lower erosion rates that the alloy with 50 atomic per cent ruthenium.
3. The addition of boron did not improve the resistance to erosion of the experimental spark plugs.
4. The performance of the spark plugs and the resulting engine performance was in all respects similar to results obtained by using standard commercial spark plugs.
5. Solid-state welding had taken place between the experimental electrode inserts and the nickel sheath,

demonstrating that the experimental material can be successfully bonded to nickel.

6. Voltage demand and spark-over time for the experimental spark plugs compared favourably with those of commercial spark plugs containing nickel or gold-palladium centre electrodes.

(v) Evaluation of electrode erosion utilising Ru-rich ruthenium aluminide (manufactured by arc melting) and unleaded fuel

Centre electrode inserts of arc-melted alloys containing 85, 90 and 95 mass per cent ruthenium were subjected to a limited (8-hour) test in an engine, running on unleaded fuel at 35000r/min and full load. A standard commercial spark plug with a gold-palladium centre electrode was used as reference in this experiment to compare erosion results.

The following results were obtained:

1. Less erosion occurred on the ruthenium aluminide insert than on the gold-palladium insert. (2,3 μm for the alloy containing 85 mass % Ru versus 30,1 μm for the gold-palladium insert).
2. An optimum composition for erosion resistance of ruthenium and aluminium exists between 80 and 95 mass per cent ruthenium for unleaded fuels.

(vi) Evaluation of electrode erosion utilising Ru-rich ruthenium aluminide (manufactured by hot isostatic pressing) in unleaded fuel

Centre electrode inserts of 1,0 mm diameter were manufactured from the following ruthenium aluminide materials:

TABLE 3

SAMPLE NO.	Ru PER CENT		Al PER CENT		BORON PER CENT	
	ATOMIC	MASS	ATOMIC	MASS	ATOMIC	MASS
R 95	53	(80,86)	47	(19,14)	0	0
R104	58	(83,80)	42	(16,20)	0	0
R 98	63	(86,45)	37	(13,55)	0	0
R101	68	(88,84)	32	(11,16)	0	0
R100	52,735	(80,79)	46,765	(19,13)	0,5	0,08

Spark plugs containing these inserts were tested in an engine that was run on unleaded fuel at full load at the engine speed where peak torque is delivered. A standard spark plug with a nickel-base centre electrode of diameter 2,52 mm was fitted as a reference. The face of the RuAl electrodes was therefore 0,79 mm^2 compared to that of 4,99 mm^2 of the reference nickel electrode. The sparking surface of the reference nickel electrode was therefore more than six times larger than that of the ruthenium aluminide electrode inserts.

After 72 hours, electrode wear was measured. The addition of boron did not improve the resistance to erosion.

The average erosion rate over the face of the reference nickel electrode was 0,8 μm per hour, and at the centre it was 0,35μm per hour.

The results indicate that an optimum Ru-content exists at or close to the eutectic composition of 70,61 atomic per cent Ru.

The test was continued for another 144 hours at the engine speed where peak torque is delivered and with a wide open throttle. Two spark plugs with electrodes of each of the following compositions were fitted for this test:-

1. 63 atomic per cent Ru and 37 atomic per cent Al [86,45 mass % Ru]: One spark plug not used before and one previously used in the 72-hour test described above.
2. 68 atomic per cent Ru and 32 atomic per cent Al [88,84 mass %Ru]: One spark plug not used before and one previously used in the 72-hour test described above.
3. Standard nickel-base: One spark plug not used before and one previously used in the 72-hour test described above.

Electrode erosion was again measured after 144 and 216 cumulative test hours. Erosion measured over the face of the reference electrode was misleading, because sparking also occurred from the side of the centre electrode facing the positive electrode. This led to low erosion rates measured at the electrode centre and over the electrode face of the reference spark plug.

The average erosion rate over the face of the reference nickel-alloy electrode was similar after 72, 144 and 216 hours. It was evident that a limited amount of sparking occurred from the nickel base supporting the insert, while sever erosion was measured at the corresponding. edge of the reference electrode. Table 4 shows the results obtained.

TABLE 4

Erosion rates after an additional 144 hours endurance testing			
AREAS WHERE EROSION WAS MEASURED	**EROSION RATE (μm/h)**		
	72 hours	**144 hours**	**216 hours**
Ni BASED REFERENCE ELECTRODE			
Spark Face	0,80	0,70	0,77
Electrode Centre	0,35	0,40	0,41
Side Facing Pos. Electrode	0,71	0,78	0,93
AVERAGE	0,62	0,63	0,70
EXPERIMENTAL PLUG - (68 ATOMIC % Ru)			
Spark Face	0,47	0,83	0,99
Electrode Centre	0,11	0,53	0,60
Side Facing Pos. Electrode	0,20	0,18	0,12
AVERAGE	**0,26**	**0,67**	**0,57**
EXPERIMENTAL PLUG - (63 ATOMIC % Ru)			
Spark Face	0,58	0,76	2,47
Electrode Centre	0,14	0,85	2,16
Side Facing Pos. Electrode	0,10	0,26	0,22
AVERAGE	**0,27**	**0,62**	**1,62**

The erosion resistance of the ruthenium aluminide alloys were comparable to that of the reference nickel-alloy electrodes irrespective of the fact that the reference nickel electrode had a sparking surface more than 6 times larger than that of the experimental ruthenium aluminide electrodes.

After 144 and 216 test hours, the reference nickel-alloy electrodes showed very stable erosion on the sparking surface of the centre electrode end. The 63 atomic per cent Ru alloy apparently showed a sharp increase in erosion after 72 hours testing. This observation is based on one sample only. The 68 atomic per cent ruthenium alloy compared exceptionally well with the reference nickel-alloy electrodes of some 6 times the size (effective area).

In order to obtain erosion results for nickel-alloy electrodes and ruthenium aluminide electrodes of the same diameter, ruthenium aluminide inserts containing 68 atomic % Ru, and of 1 mm in diameter and commercial nickel-alloy electrodes machined to 1 mm diameter were tested simultaneously for 60 hours in the same six-cylinder engine described previously on unleaded fuel at full load at the engine speed where peak torque is delivered. Erosion results were as follows:

TABLE 5

EROSION MEASURED AT:	EROSION RATE (μm/h)*	
	Ni	Ru-Al
The Electrode Centre	0,63	0,12
Over the Electrode Face	1,00	0,40
The side of the Electrode facing the positive electrode	0,28	0,23
Average	0,64	0,25

This also proved that results previously obtained with ruthenium aluminide inserts were reproducible.

(vii) Alloys containing nickel, ruthenium and aluminium

In addition to additions of ruthenium to the RuAl-base materials, it is envisaged that nickel can be added to the RuAl phase in such a way that part of the ruthenium is substituted with the cheaper nickel, without deleteriously affecting the desirable properties of the RuAl-base phase. This type of substitution is considered possible because both Ru and Ni form B2 (body centred cubic) aluminide compounds with aluminium, and the atomic radii and electronegativities of Ru and Ni are sufficiently close to allow the substitution of one for the other in the crystal lattice of RuAl. (The metallic atomic radius of Ru is 0,133 nm while that of Ni is 0,124 nm, and the electronegativities are 2,2 and 1,8 respectively).

This was tested by preparing a series of alloys, the compositions of which are given in Table 6, by arc melting. The alloys were perceived to have a structure $Ni_xRu_{1-x}Al$.

TABLE 6

Composition of test samples, atomic %				
Sample	x	Ru	Ni	Al
NH-0	0	50,0	0,0	50,0
NH-1	0,25	37,5	12,5	50,0
NH-5	0,51	25,0	25,0	50,0
NH-2	0,75	12,5	37,5	50,0
NH-4	1,00	0	50,0	50,0

The alloys were then examined using metallography, X-ray diffraction and hardness testing. It was found that the addition of Ni to RuAl, or Ru to NiAl, raised the hardness of the material considerably.

The tests indicated that in the Ni-Al-Ru ternary system, compounds with the general formula $Ni_xRu_{1-x}Al$ have the same B2 structure and Ni can substitute at least partially for Ru. Ni can also substitute for Ru in other parts of the Ru-Al phase system e.g. in the Ru-rich sections where high durability of electrode inserts has been proven experimentally. Ni-Al-Ru alloys with a combined Ru+Ni content of 42 or more atomic per cent, are suitable to be used in spark plug electrodes.

The fact that Ni atoms can substitute for Ru atoms explains the diffusion bonding that was observed to have taken place during engine operation. Diffusion bonding as well as other welding techniques such as (but not limited to) electrical resistance welding can be harnessed as a production technique, in particular to bond tips, of or containing, intermetallic compounds to a nickel or nickel alloy electrode.

OTHER METALLIC COMPOUNDS, DESIGNS AND PROCESS ROUTES

It will be understood that numerous different binary and ternary intermetallic compounds with melting points above 1400°C and materials containing such compounds may be used to form spark plug electrodes or tips or inserts for electrodes without departing from the scope hereof. A few examples of many other binary intermetallic compounds that may be sued for form electrodes are materials comprising essentially of

- nickel and aluminium,
- platinum and aluminium (compositions as described in our U.S.A. patent 17/0/127),
- titanium and aluminium,
- ruthenium and tantalum,
- iron and aluminium,
- niobium (columbium) and aluminium,
- molybdenum and silicon,
- iridium and niobium (columbium), and
- ruthenium and titanium,
- hafnium and iridium,
- ruthenium and zirconium,
- iridium and titanium,
- iridium and tantalum.

It will be further understood that compositions may deviate from stoichiometric intermetallic compositions and may therefore include multi-phase structures without departing from the scope hereof.

Intermetallic compounds with melting points above 1400°C in a matrix of other metals may according to this invention be produced in any ratio by means of any suitable process. For example, powdered or sub-divided intermetallic material may be embodied in a ductile metallic phase thus yielding a composite material embodying good arc erosion resistance and good workability. A dispersion of intermetallic phases with melting points above 1400°C may also be used to restrict grain growth of a ductile metallic phase of a multi-phase or composite material at elevated temperatures. The ductile metallic phase could include metals such as Ni, Pt, Au, Pd, Ag, or any other suitable metal or any combination of such metals.

It will also be understood that, numerous different geometric configurations of positive and negative spark plug electrodes containing intermetallic compounds may be designed without departing from the scope hereof. For example, the intermetallic material may be sintered into the ceramic insulator body to form a centre electrode.

Apart from arc melting and reactive hot isostatic pressing, the intermetallic material may be manufactured by a number of different processes without departing from the scope hereof. These include a variety of powder metallurgical processes, a variety of metal-spraying processes and a number of melting techniques.

Spark plugs and igniters typically also contain ceramic components such as alumina insulators. Ceramic materials are also increasingly considered for the manufacture automotive components. The intermetallic compounds according to this invention lend themselves to sintering processes compatible with ceramic materials. It is possible to sinter ceramic components and intermetallic compounds according to this invention in one production step. Should a specific shrinkage during sintering be required, this could be achieved by mixing specific amounts of pre-reacted intermetallic powders with elemental metal powders.

Claims

1. A spark plug (3) or igniter electrode characterised in that the electrode (2), or a tip (1), or insert mounted onto or into the electrode, is made at least predominantly of one or more intermetallic compounds having a melting point above 1400°C and wherein the intermetallic compound or compounds is or are chosen to exhibit adequate toughness, resistance to thermal shock, and electrical conductivity.

2. An electrode as claimed in claim 1 in which the intermetallic compound or compounds is or are selected from the groups comprising ruthenium and aluminium (herein referred to as ruthenium aluminide); ruthenium, aluminium and nickel; platinum and aluminium; ruthenium and titanium; nickel and aluminium; titanium and aluminium; ruthenium and zirconium; ruthenium and tantalum; iron and aluminium; niobium (columbium) and aluminium; molybdenum and silicon; iridium and niobium; iridium and hafnium; iridium and titanium; iridium and tantalum.

3. An electrode as claimed in claim 2 in which the intermetallic compound is or includes ruthenium aluminide.

4. An electrode as claimed any one of the preceding claims in which the intermetallic compound is present as one phase in a dual or multi phase material.

5. An electrode as claimed in claim 4 in which the other phase is a nickel or nickel alloy material of substan-

tially conventional composition.

6. An electrode as claimed in claim 4 in which the intermetallic compound is ruthenium aluminide in an excess of ruthenium.

7. An electrode as claimed in claim 6 in which the ruthenium content of the dual phase material is from 80 to 99 mass per cent.

8. An electrode as claimed in claim 7 in which the ruthenium is present in an amount of about 90 mass per cent.

9. An electrode as claimed in any one of the preceding claims in which the electrode has a tip (1) bonded thereto and wherein the tip is made of, or contains, the intermetallic compound.

10. An electrode as claimed in claim 9 in which the tip is bonded to a nickel or nickel alloy electrode part.

11. An electrode as claimed in any one of claims 1 to 8 in which the electrode has an insert secured therein and wherein the insert is made of, or contains, the intermetallic compound.

12. A spark plug or other igniter embodying an electrode as claimed in any one of claims 1 to 12.

13. A spark plug as claimed in claim 12 in which both or all electrodes thereof are as claimed in any one of claims 1 to 11.

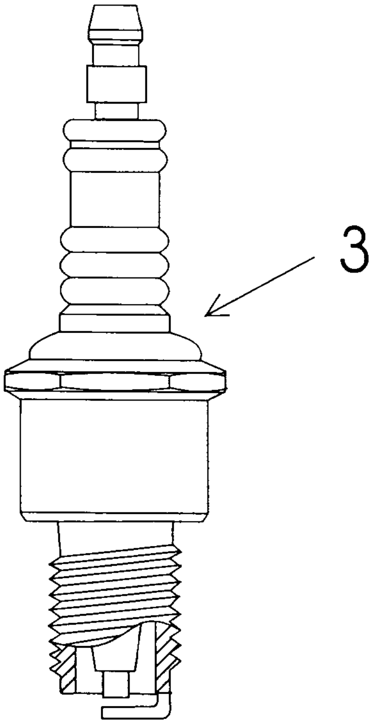

Fig 1

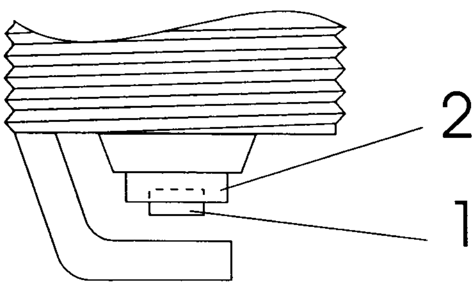

Fig 2

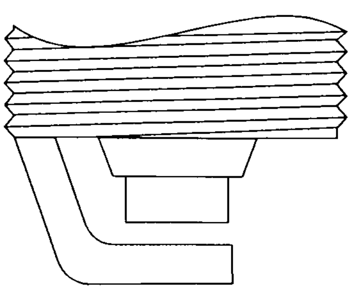

Fig 3

European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 9728

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	GB-A-2 005 649 (JOHNSON MATTHEY) * the whole document * ---	1-4,9, 11-13	H01T13/39
X	WO-A-92 10868 (ROBERT BOSCH) * the whole document * -----	1,2,4,5, 9-13	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	6 February 1995	Bijn, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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