(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 170 975 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **85109234.6**

(22) Date of filing: **23.07.85**

(51) Int. Cl.⁴: **H 01 T 13/41**, H 01 C 7/00

(30) Priority: **28.07.84 JP 158131/84**

(43) Date of publication of application: **12.02.86 Bulletin 86/7**

(84) Designated Contracting States: **DE FR GB**

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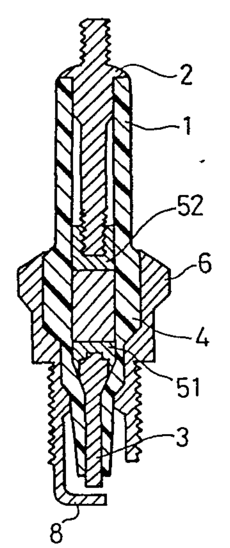
(54) **Spark plug.**

(57) A spark plug with an improved radio noise suppression effect. A magnetic substance is added to the resistor of the spark plug to enhance its absorption of high frequency radio currents. The resistor is made of a sintered material comprising, by weight, 0.2–0.6% carbon, 25–75% glass of which softening temperatures are 300–600°C and grain sizes are 10–500 µm, 0.4–40% magnetic substance and a binder constituting the rest. A current path made of carbon is formed in a zigzag shape around the glass and magnetic substance in the resistor.



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TITLE OF THE INVENTION

SPARK PLUG

BACKGROUND OF THE INVENTION

Field of the Invention:

This invention relates to an improvement of spark plugs employed in a high voltage ignition circuit of an internal combustion engine and more particularly to decrease of an energy loss and to an effective suppression of radio noises generated from the spark plug.

Description of the Prior Art:

High frequency noise currents generated from a spark plug can be suppressed, for example, by means of a high frequency radio wave absorbing circuit which is made by connecting a resistor in series with a terminal metal member fitted to an end of an internal passage of the spark plug and a center electrode fitted in the other end of the internal passage.

Conventionally, a mixture of carbon, zirconia (or alumina or magnesia) and glass baked to the internal passage of a spark plug has been known for the resistor. As illustrated in Fig.7, this resistor comprises a high resistive glass 42 and carbon (conductor) forming a current path 43 in a zigzag shape in order to improve a noise current suppression effect. (The noise current suppression effect by means of the zigzag shape of the current path 43 is hereinafter referred to as a "structural effect".)

In addition, zirconia helps carbon forming the current path 43 adhere to glass 42 and thereby reduces the irregularity of resistance and improves the durability of the resistor.

The radio noise suppression effect of the resistor composed of carbon, zirconia and glass, however, is not sufficient. Especially in view of an increasing use of electronic equipments mounted in vehicles and increasing requirements for precision thereof in recent years, a further improvement in radio noise suppression is being called for.

SUMMARY OF THE INVENTION

It is an object of this invention, therefore, to provide a spark plug with a more enhanced radio noise suppression effect by improving the above resistor.

According to this invention, a magnetic substance is added to the resistor in order to enhance the absorption of high frequency noise currents.

With reference to Fig.1 showing a sectional view of a spark plug of this invention and Fig.2 showing the composition of the resistor utilized in the spark plug, the spark plug of this invention comprises an insulator 1 having an internal passage extended in the axial direction of the spark plug, a terminal metal member 2 fitted to an open end portion of the internal passage, a center electrode 3 fitted to the other open end portion of the internal passage, and a resistor 4 positioned between the terminal metal member 2 and the center electrode 3 inside the internal passage, the resistor 4 is made of a sintered material comprising, by weight, 0.2 - 0.6 % carbon, 25 - 75 % glass of which the softening temperatures are 300 - 600°C and the particle diameters are 10 - 500μm,0.4 - 40 % magnetic substance and a binder constituting the rest.

Except for the resistor 4, conventional structural members may be used for such parts of the spark plug of this invention as the insulator 1, terminal metal member 2 and central electrode 3.

The structure of the resistor 4 is considered to become like the one shown in Fig.2 comprising glass 42 of which particle sizes are about 10 - 500 μm, magnetic substance 41 and current path 43 mainly made of carbon and formed in a zigzag shape. The carbon is dispersed by the binder to adhere well to the glass 42 and magnetic substance 41. Materials such as zirconia, alumina, magnesia and glass of which grain sizes are less than about 5 μm may be employed for the binder.

The magnetic substance 41 absorbs high frequency noise currents, i.e., the magnetic substance 41 reduces high frequency noise currents by converting the energy of the noise currents to the magnetization energy of the spin of the magnetic substance 41 and/or to a joule heat. Therefore, the relative permeability of the magnetic substance 41 is required to be more than 10.

The following may be used for the magnetic substance 41.

a. Ferrite of a reverse spinel structure composed of $M^{II}O \cdot Fe_2O_3$ (beryllium (Be), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), magnesium (Mg), cadmium (Cd), lithium (Li) or a compound material thereof is employed for the bivalent metal M^{II}.).

b. Hexagonal crystal ferrite such as $BaO \cdot 6Fe_2O_3$, $PbO \cdot 6Fe_2O_3$ and $SrO \cdot 6Fe_2O_3$.

c. a compound of the a and the b

d. garnet ferrite ($3R_2O_3 \cdot 5Fe_2O_3$)

(yttrium (Y), samarium (Sm), europium (Eu), cadmium (Cd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu) are employed for the R.)

The proportion of the magnetic substance to the resistor is limited to 0.4 - 40 wt%. When less than

0.4 wt% magnetic substance is contained in the resistor, the resistor could not show the above effects. On the other hand, when more than 40 wt% magnetic susbtance is contained, due to the large energy loss at a low frequency, the performance is deteriorated.

Further, particle diameters of the magnetic substance are limited to 10 - 300 μm. When particle diameters of the magnetic substance are less than 10μm, the magnetic substance melts into the glass by its reaction with the glass in a heating process and thereby causes its magnetic property to be lost, its absorption of high frequency noise currents to decrease and its magnetic domain to be lost.

Should particle diameters of the magnetic substance be larger than 300μm, a gap tends to occur between the magnetic substance and the glass because the glass softens at a high temperature while the magnetic substance does not, and thus the stability and durability of the resistor 4 decrease. In addition, the specific resistance of the magnetic substance should exceed 10^{-1} ohm·cm. When the specific resistance is less than 10^{-1} ohm·cm, the magnetic substance becomes conductive and thus the current path of the resistor 4 becomes too wide to obtain the aforesaid structural effect.

The glass 42 is considered to work as an obstacle to electric currents and forms the current path

43 in a zigzag shape.

The softening temperatures of the glass 42 should be about 300 - 600°C. The softening temperature of the glass 42 is preferably more than about 300°C because the spark plug is heated to about 250°C in its use. And the temperature is preferably less than 600°C in order to weld the resistor 4 inside the insulator 1 without oxidizing the terminal metal member 2 and the center electrode 3. Such glass as lithium (Li) glass, silica (SiO_2) glass, borosilicate glass not including lithia (Li_2O), and soda zinc glass may be employed for the glass 42.

Proportion of the glass to the resistor 4 is limited to 25 - 75 wt%. The aforesaid structural effect cannot be obtained sufficiently when the glass content in the resistor 4 is not more than 25 wt% and the amount of the magnetic substance 41 contained in the resistor 4 becomes too little if the glass content exceeds 75 wt%.

Grain sizes of the glass 42 are preferably about 10 - 500μm. Should the grain diameters be less than 10μm, the glass 42 tends to soften in a normal use of the spark plug, and thereby the current path becomes unstable, and should the grain diameters exceed 500μm, a gap tends to occur between the glass and the current path when the resistor 4 is being welded inside the insulator 1.

The current path 43 comprising 0.2 - 0.6 wt%

carbon (conductor) and a binder constituting the rest are formed in a zigzag shape around the glass 42 and the magnetic substance 41.

The spark plug of this invention is manufactured by filling and sintering and welding the resistor 4 between the terminal metal member 2 and the center electrode 3 inside the insulator 1. The welding temperatures are generally about 900°C.

The spark plug of this invention includes the glass 42 and magnetic substance 41 which work as obstacles to radio noise currents and form the current path 43 in a zigzag shape and thereby provides the aforesaid structural effect. Further the magnetic substance 41 suppresses generation of radio noise currents by absorbing high frequency noise currents as mentioned before.

BRIEF DESCRIPTION OF THE DRAWINGS

The exact nature of this invention, as well as other objects and advantages thereof, will be apparent from the consideration of the following specific particularly when considered in connection with the accompanying drawings in which:

Fig.1 is a cross sectional view showing the practical structure of the spark plug according to the embodiment of the present invention;

Fig.2 is a structural view showing the microscopic structure of the resistor employed in the sprak plug of the present invention;

Fig.3 is a graph showing the measurement of the frequency characteristics of intensity of the noise-field radiated from the sprak plug according to the embodiment of the present invention in comparison with the conventional spark plug;

Fig.4 is a graph illustrating the noise suppression effect of various magnetic substances added in the resistor;

Fig.5 is a graph illustrating the noise suppression effects of magnetic substances with various particle sizes added in the resistor;

Fig.6 is a schematic illustration showing a measurement method of noise field intensity:

Fig.7 is a structural view showing the microscopic structure of the resistor employed in the conventional spark plug:

Fig.8 is a graph showing the measurement of the noise suppression effect using resistors with varied composition ratio of ferrite; and

Fig.9 shows the composition of the resistor of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is explained hereunder in detail with a description of a preferred embodiment thereof.

An embodiment of the spark plug of this invention and comparative models were manufactured as follows. All of the spark plugs are shaped as illustrated in Fig.1.

A mixture of carbon, glass whose grain size was 5μm and zirconia at a proportion of 1 : 7.5 : 29 were dry-grounded for 2 hours by means of a vibration mill to produce a material for the current path. The glass was composed, by weight, of 52 % SiO_2, 7 % CaO, 37 % B_2O_3, and 4 % Li_2O.

Thereupon, 22.5 % current path material thus prepared,72.5 % glass whose grain size is 200μm, and 5 % nickel zinc ferrite, by weight, were mixed together with a dextrine aqueous solution and a carboxymethylcellulose aqueous solution. And then the mixture was dried and sieved to obtain a resistor material whose grain size was 200μm.

The nickel zinc ferrite was composed of 35 mol % NiO, 15 mol % ZnO, and 50 mol % Fe_2O_3.

In place of the nickel zinc ferrite, resistor materials respectively made of super permalloy and zinc oxide ferrite were also manufactured for the purpose of comparison as shown in a table.

Resistors with varied composition weight

T A B L E

	1	2	3	4	5
	SUPER PERMALLOY	ZnO FERRITE	Ni-Zn FERRITE	Ni-Zn FERRITE	ZnO FERRITE
COMPOSITION (wt%)	Fe 16 Ni 79 Mo 5	ZnO 90 Ni FERRITE 10	Ni 35 Zn 15 Fe_2O_4 50	Ni 35 Zn 15 Fe_2O_4 50	ZnO 95 Ni FERRITE 5
SPECIFIC RESISTANCE (ohm·cm)	10^{-4}	10^{-1}	10^{4}	10^{6}	10^{-1}
RELATIVE PERMEABILITY	10^{4}	20	150	400	10
NOTE			SINTERING AT 1400°C	SINTERING AT 1250°C	

ratio of ferrite were also manufactured. Fig.8 is a graph showing the measurement of the noise suppression effect using the resistors.

The center electrode 3 was inserted in the lower end of the internal passage of the insulator 1 (alumina), then 0.26 g of copper glass which was a mixture of glass composed, by weight,of 64 % SiO_2, 6 % Al_2O_3 , 23 % $B_2O_3$and 7 % Na_2O and copper powder at a proportion of 1 : 1 was filled on the center electrode 3, then a pressure of 1,400 kg/cm^2 was applied onto the copper glass, then 0.5 g of the above-mentioned resistor material was added on the copper glass and a pressure was applied thereon in two successive process, then 0.46 g of the copper glass was placed on the resistor material, and then a pressure of 1,100 kg/cm^2 was applied on the copper glass by means of terminal nut. Then the spark plug was placed in a furnace for thirty minutes at a temperature of 870°C to soften the glass contained in the materials of the copper glass and resistor. Then the spark plug was taken out of the furnace and a pressure of 1,000 kg/cm^2 was applied onto the terminal nut, and thereby the resistor material became the resistor 4 and the two pieces of copper glass become respectively the copper glass electrodes 51 and 52. In addition, the resistance value of the resistor 4 was controlled to comply with Japanese Industrial Standard (JIS).

After the insulator 1 was cooled, the housing 6 having an earth electrode 8 was placed around the insulator 1 to obtain the spark plug shown in Fig.1.

For the purpose of comparison, a conventional spark plug A was also manufactured in the same process. The resister of the conventional spark plug A was composed, by weight, of 0.9 % carbon, 22.5 % zirconia, 4.5 % glass whose grain sizes are small, and 72.5 % glass whose grain sizes are large.

The noise field intensity was measured with each spark plug to evaluate its noise suppressing effect. The results are shown in Figs.3 - 5. To measure the noise field intensity of the spark plugs, each spark plug was placed under 4 barometric pressures approximately equivalent to the pressure in an engine. Then a discharge aging was done for several minutes at a rotation of 2,000 rpm. Thereupon, noise field intensity was measured at various frequencies by means of a noise measuring apparatus shown in Fig.6. And, the measured values shown in Fig.3 - 5 were maximum values measured at each frequency.

With reference to Fig.3 showing the noise field intensity of the embodiment of the spark plug of this invention and the comparative model A, the noise field intensity of the embodiment is distinctly lower than that of the comparative model A at every frequency. Accordingly, the radio noise suppressing effect is enhanced by the spark plug of this invention.

Referring now to Fig.4 showing the noise suppression effects of the spark plugs, each of which is made of one of the five kinds of magnetic substances with different specific resistances and relative permeabilities indicated in Table 1; with the comparative model A being with criterion of comparison, the noise suppression effect of this invention can be obtained when the specific resistances are larger than 10 ohm cm and the relative permeabilities are more than 10.

As can be seen in Fig.5 showing a comparison of noise suppression effects of various grain sizes of nickel zinc ferrite indicated as No.3 in Table 1, one of the necessary conditions for obtaining the effects of this invention is the grain sizes of the magnetic substance are larger than 10μm.

FIG.8 is a graph showing the measurment of the noise suppresstion effect using the resistors with varied composition weight ratio of ferrite. Since too little binder will result in instability of the resistance value, not less than 20 wt% binder is preferable. Conversely, when the binder is not less than 40 wt% and the ferrite is not less than 40 wt%, the noise suppression effect is reduced because the ferrite cannot be sealed with the binder and glass of 200μm in grain size. Fig.9 shows the composition of the carbon and binder, the ferrite and the glass in the resistor of the present invention.

The spark plug of this invention is provided with a high frequency radio wave absorbing circuit for suppressing radio noises which comprises a resistor connected between a terminal metal member and a center electrode in series. A magnetic substance, of which grain sizes of the glass are large, carbon and binder are employed for the material of the resistor of the spark plug.

As set forth in the detailed description of the embodiment, the spark plug of this invention absorbs high frequency radio noises by means of a magnetic substance and the current path formed in a zigzag shape by glass, of which grain sizes are large, and the magnetic substance, and thereby inhibits radio noises.

Thus, the radio noise suppression effect of the spark plug of this invention is greatly enhanced as compared with conventional spark plugs.

Therefore, when the spark plug of this invention is employed in a high voltage ignition circuit of internal combustion engine, ill effects caused by radio noises for various electronic equipments mounted in a vehicle can be prevented. This invention may be embodied in other specific forms without departing from the spirit or essential characteristic thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claim rather than by the foregoing description and all changes which come within the meaning and range of equivalency of the claim are therefore intended to be embraced therein.

WHAT IS CLAIMED IS:

1. A spark plug comprising:

an insulator having an internal passage extended in the axial direction of said spark plug,

a terminal metal member fitted to an open end of said internal passage of said insulator,

a center electrode fitted in the other open end of said internal passage of said insulator, and

a resistor positioned between said terminal metal member and said center electrode inside said internal passage of said insulator,

said resistor is made of a sintered material comprising, by weight, 0.2 - 0.6 % carbon, 25 - 75 % glass of which softening temperatures are 300 - 600 °C and grain sizes are 10 - 500 μm, 0.4 - 40 % magnetic substance and a binder constituting the rest.

2. The spark plug according to claim 1,

in which the composition of said resistor includes a current path made of carbon dispersed in said binder and formed around said glass and said magnetic substance.

3. The spark plug according to claim 1,

in which said binder includes at least two of such elements as zirconia, alumina, magnesia and glass of which grain sizes are less than 5 μ m.

4. The spark plug according to claim 1, in which specific resistance of said magnetic substance is more than 10 ohm cm and relative permeability is more than 10.

5. The spark plug according to claim 1, in which particle diameters of said magnetic substance is more than 10μm.

6. The spark plug according to claim 1, in which said magnetic substance is ferrite of a reverse spinel structure composed of $M^{II}O \cdot Fe_2O_3$.

7. The spark plug according to claim 1, in which said magnetic substance is hexagonal crystal ferrite.

FIG.1

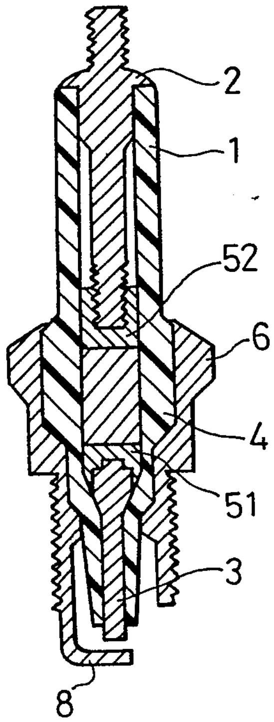


FIG.2

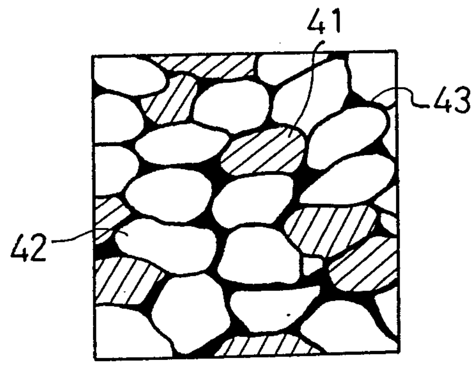


FIG.3

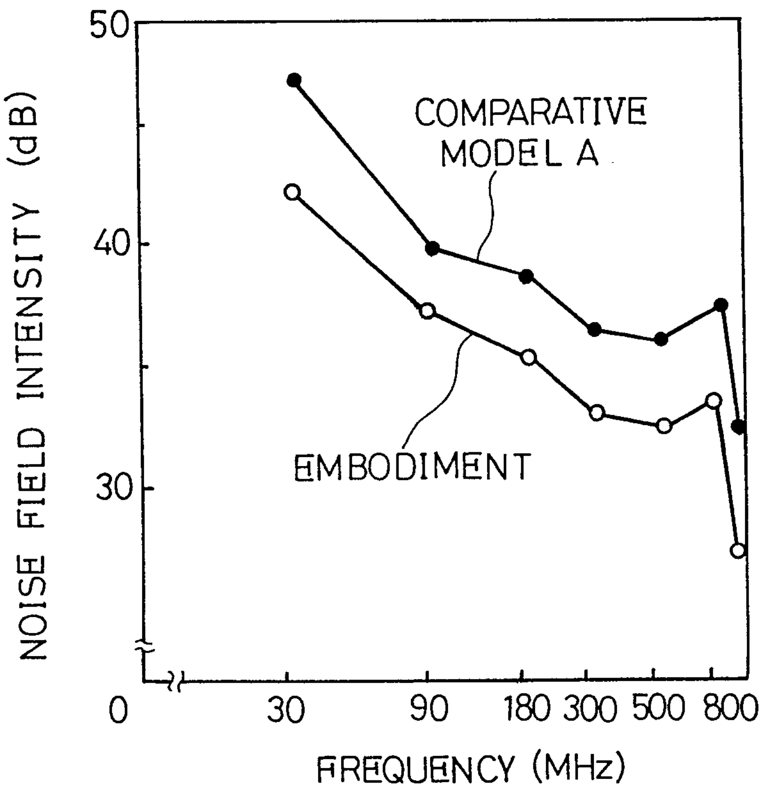


FIG.4

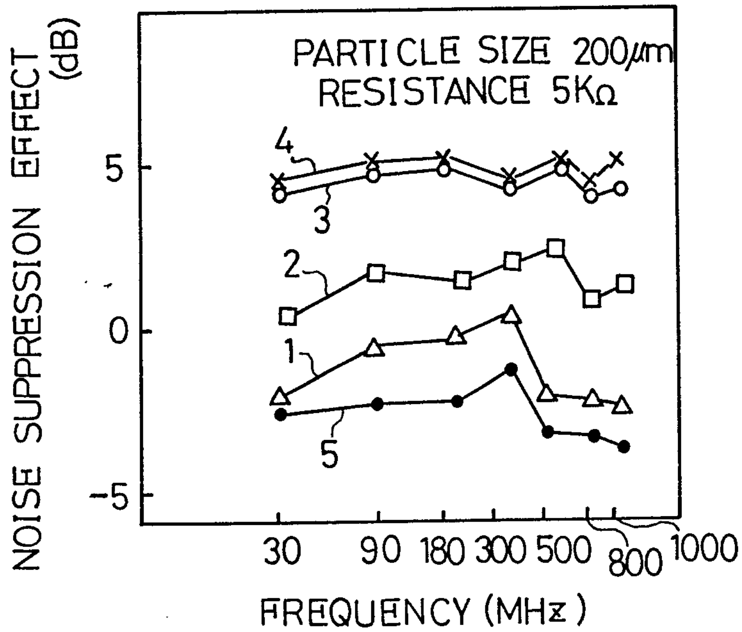


FIG.5

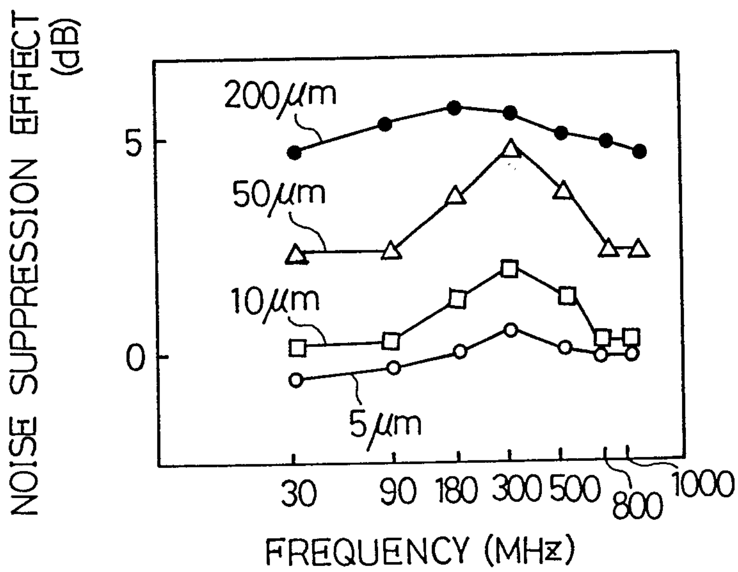


FIG.6

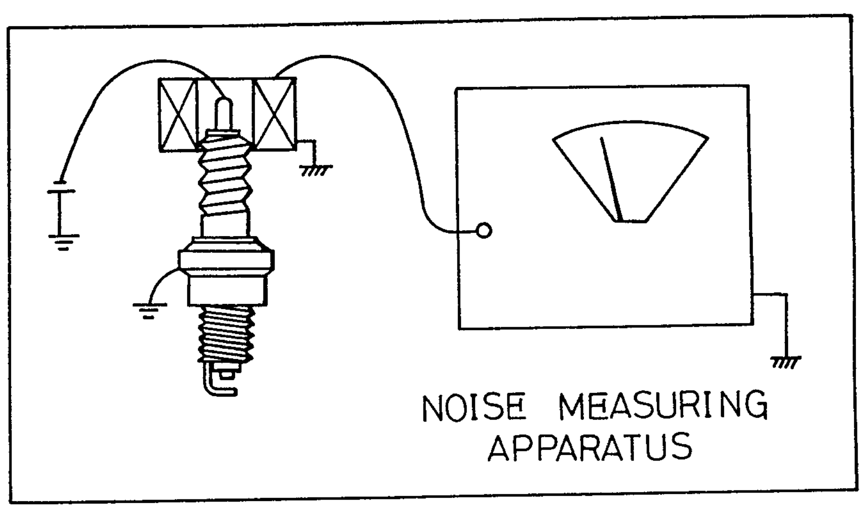


FIG.7

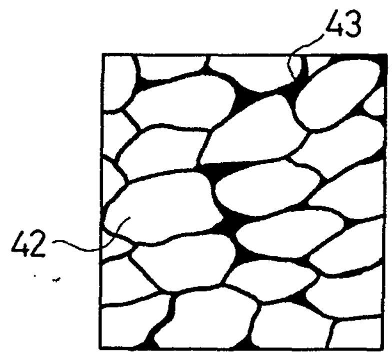


FIG.8

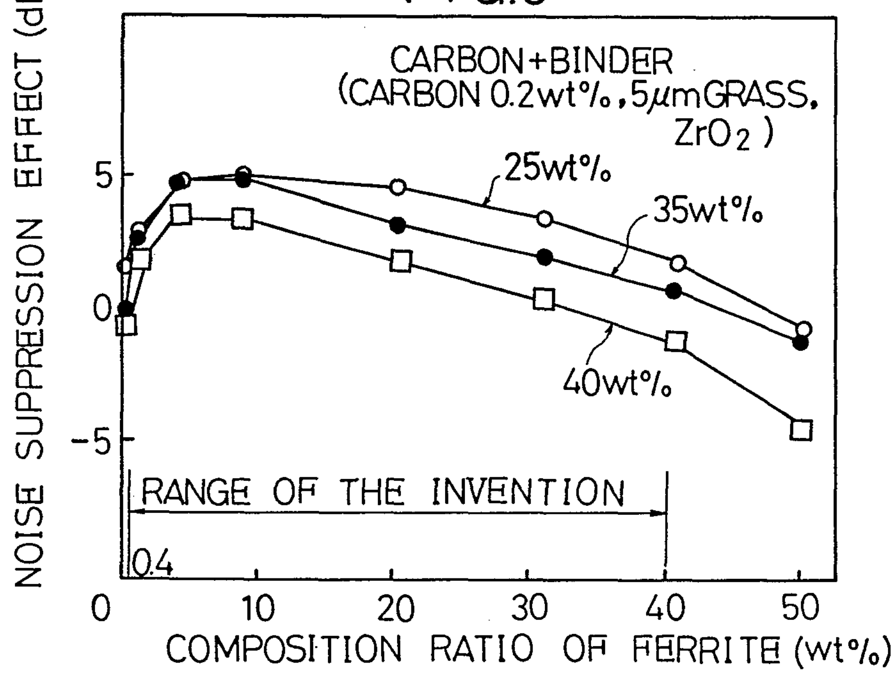
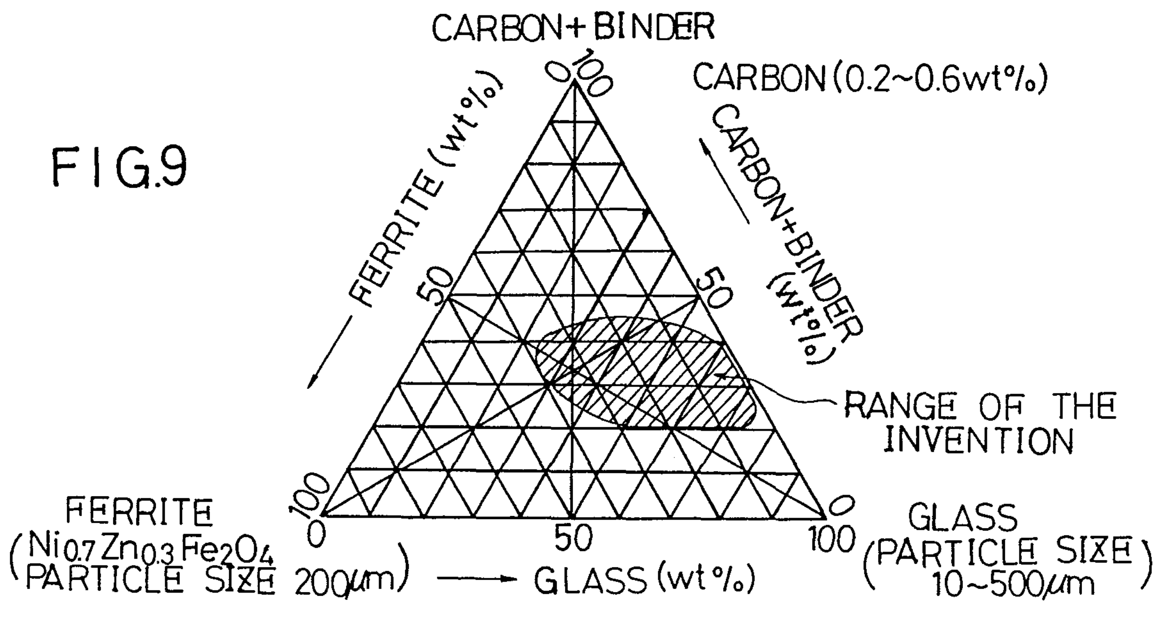


FIG.9



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EUROPEAN SEARCH REPORT

0170975

Application number

EP 85 10 9234

Category	DOCUMENTS CONSIDERED TO BE RELEVANT Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	DE-A-3 026 374 (HITACHI) * Page 2, lines 10-13; page 8, lines 17-24; figure 1; page 9, lines 5-24 * ---	1-3	H 01 T 13/41 H 01 C 7/00
A	FR-A-1 162 823 (BOSCH) * Page 1, left-hand column, line 27 - right-hand column, line 9 * ---	1	
A	FR-A-2 270 699 (NIPPON DENSO) ---		
A	DE-A-3 226 340 (NGK. SPARK PLUG) -----		TECHNICAL FIELDS SEARCHED (Int. Cl.4) H 01 T 13/00 H 01 C 7/00 H 04 B 15/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	04-11-1985	BIJN E.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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