Development of High Performance DC Fuse for Electric Vehicle and Its Features

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Abstract

The voltage of power circuits used in electric vehicles has increased to 500 V or more. This shift to higher voltages is done to reduce current, harness weight and improve motor-controller's efficiency. The fuses that protect these circuits must shut out DC arcs, yet their performance needs improving. This paper reports the development of a formidable fuse that coats a thin film of hydrogen strage Titanium on copper foil, and its features. This new fuse has shown great potential in protecting high voltage circuits of future electric vehicles, and other high voltage DC electric devices.

Keywords

electric vehicle fuse, arc discharge, titanium, thermal spray

1. INTRODUCTION

It is hard to break high voltage DC arcs. Because of this, fuses made with conventional SiO_2 powder are unreliable for the 500V or more than 1000 V used for electric vehicles, etc. To protect electric vehicle harnesses and electronic circuits such as inverters, a trip time of about 1 ms is required and development is now an urgent issue. We already developed a new type of fuse using hydrogen strage alloy knowing that hydrogen is effective in breaking arcs [Minami et al., 2003]. Because it uses a low temperature acting hydrogen storage alloy, safety and productivity are difficult issues.

Titanium releases hydrogen at about 600℃ and can be stably impregnated with it, therefore the idea of the new fuse applied these principles. By coating the hydrogenated Titanium on copper or other fuse, it is hoped that the hydrogen will cover the arc and thus break it. Titanium has a high electrical resistance and is unsuited as a fuse itself. The fuse body requires a material of high conductivity such as copper.

It is thought to heat Titanium powder at high voltage and high current, accelerate it by electromagnetic force in a hydrogen atmosphere and directly coat the copper when an appropriate newly plasma gun can be developed. It is expected that the hydrogen storage Titanium could be coated on the surface without melting the copper. A method for accelerated and melted powder using electromagnetic force to create a thin film was developed some time ago by Usuba et al [2002]. Under the Patent 3331375, the powder itself is ionized and accelerated by the electromagnetic force. Therefore, only conductive powders can be used. Also by this method, the powder must be set in a device each time to discharge, which is not only expensive to make but it also has not considered Titanium occlusion in hydrogen.

2. EXPERIMENT METHOD

As a method of fabrication of new-type fuse, it is thought to place the powder in a vacuum tube and a plume of gas is injected through a valve by pulsed current, then a pulsed high voltage is applied between the two electrodes as shown in Figure 1. The powder is accelerated by electromagnetic force based on the gas discharge. The melted Titanium powder is hit by the cupper coated ceramics and formed a thin film structure.

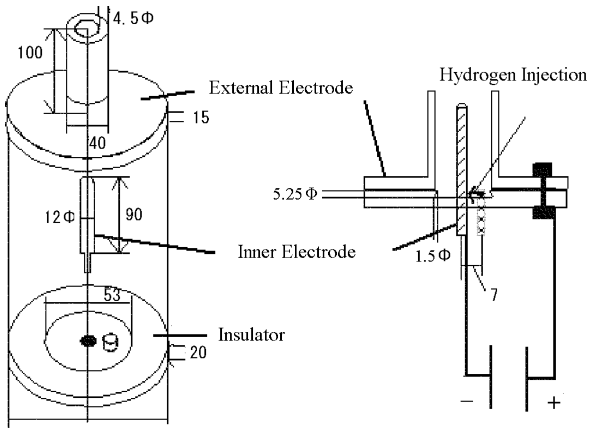

Fig. 1 An illustration of the powder injector

A fuse of high speed breaking performance can be made using Hydrogen storage Titanium powder coated on the fuse body. With this film forming method, discharging occurs because of the injected hydrogen gas. The powder is then accelerated between the electrodes using the electromagnetic force generated at that time. Accordingly, even nonconductive powders can be accelerated and formed into films. The method patented by Usuba et al. [2003] can not use gas. Moreover, it requires tedious operation via a valve or other means to inject the powder just prior to impressing the discharge power supply.

We have already developed the idea of using hydrogen storage alloy working at the temperature of about 100 deg.C which shows successful performance for breaking DC arching [Minami et al, 2003]. To fabricate this type of fuse, however, needs a lot of works and costs not effective. This newly designed method to produce hydrogen storage Titanium on the surface of the cupper film seems to be low-cost and needs not much labour.

3. EXPERIMENTAL RESULT

Figure 1 shows the experimental setup. When triggered, the solenoid valve is opened and the acting hydrogen is injected into the vacuum tube. Discharging is started after gas injection using a delayed pulse generator.

The electrodes are coaxial, separated by an insulating plate and connected to the pulse power supply circuit. A solenoid valve is attached to the bottom of the insulating plate and injects acting gas between the electrodes. This swirls the powder up between the electrodes (Figure 2).

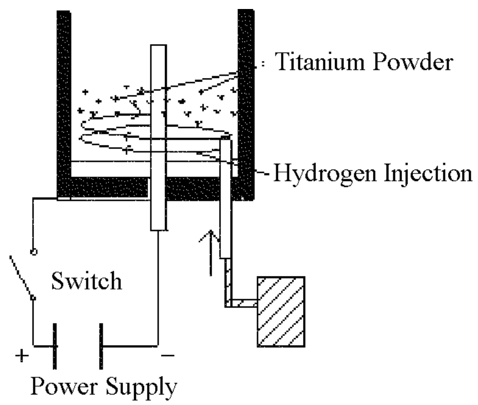

Fig. 2 An image of the ignition mechanism of the discharging

The aforementioned setup starts discharging. Figure 3 shows the basic configuration of the electrodes in the vacuum tube and how it operates. In this experiment, Titanium powder is used. Before charging the energy storage capacitor, Titanium powder is placed between the electrodes of Figure 3, the substrate is positioned a set distance from the electrodes and a vacuum is drawn. After a sufficient degree of vacuum is attained, the power supply capacitor bank (5 kV, 800 μF) can be discharged. The acting gas is injected by a timing system connected to the ignitron switch and the Titanium powder swirled upward as shown in Figure 3. While the powder is set between the electrodes, the ignitron tube switch is thrown to start arc discharge between the electrodes and the hydrogen is ionized as shown in Figure 4. Electromagnetic force, JxB is generated by the magnetic field of the discharge current, and the plasma is accelerated. This electromagnetically accelerated plasma is heated and the powder is accelerated (Figure 5). The film is then formed on the substrate as shown in Figure 6.

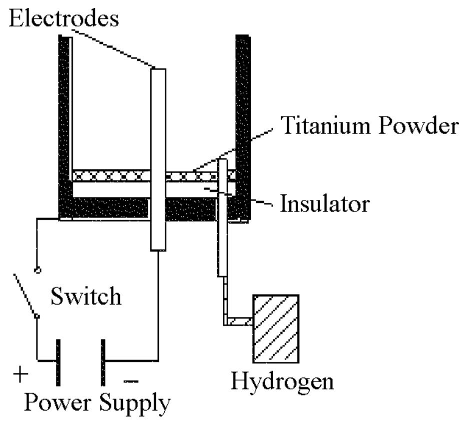

Fig. 3 The experimental set up of the experiment

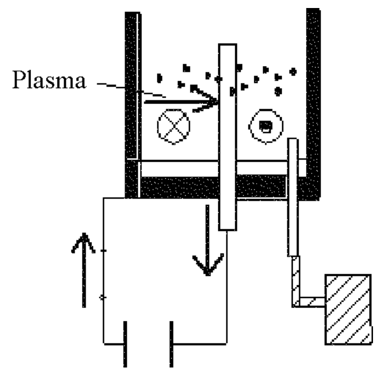

Fig. 4 The mechanism of plasma acceleration due to JxB force

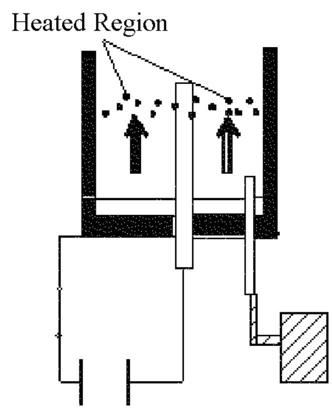

Fig. 5 The image of the accelerated hydrogen plasma with the powder

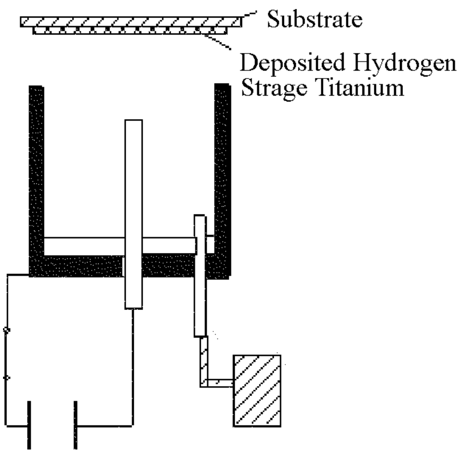

Fig. 6 An illustration of the deposited Titanium film

By forming a Hydrogen storage Titanium film on the copper foil, a high performance fuse of short arc generation time is made as shown in Figure 7. The result shows that a fuse made without hydrogenated Titanium, whereas Figure 8 shows the fuse without a Titanium film. Arc breaking time is 50 ms for the fuse of Figure 8, but it is approximately 1 ms for the fuse shown in Figure 7.

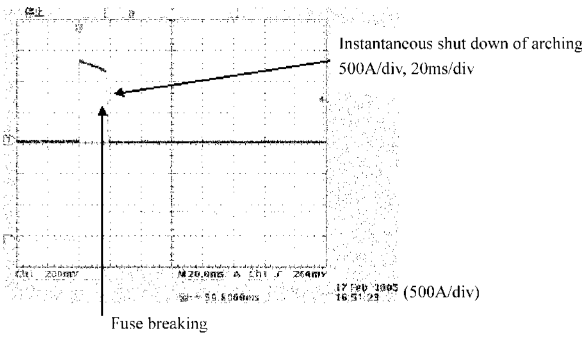

Fig. 7 An example of newly developed fuse characteristics during the fuse breaking

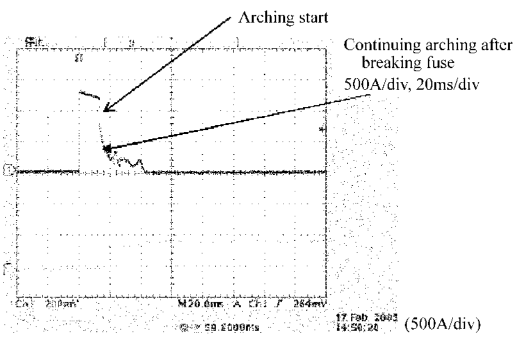

Fig. 8 An example of non Titan coated fuse characteristics

4. DISCUSSION AND CONCLUSION

This newly developed device can accelerate powder electromagnetically and a thin film of hydrogen coated Titanium on a substrate is made using gas discharge. When this thin film is deposited on the surface of a fuse, negative ions made of Hydrogen discharge that stops maintaining arcs, hence making a fuse that blows at a high speed. In fact, a prototype fuse exhibited a breaking time of 1 ms. The production cost of this method seems to be lower than the previous method using low temperature hydrogen storage metal powder contained in a cylindrical fuse [Minami et al, 2003]. It is expected that this fuse will spread on applications with electric vehicles as well as other high voltage power supply.

This result also suggests that even nonconductive powders can be accelerated by electromagnetic force using gas plasma discharge and formed as films. Moreover, using a hydrogen acting gas, it is possible to hydrogenate Titanium powder and deposit on a substrate. New material production using this method is expected.

References

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