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題目(和文)	ハイブリッド直流スイッチのアークレス開閉を実現する電気接点物理の研究
Title(English)	Study on Electric Contact Phenomena in Hybrid DC Switches with Arc-less Commutation
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Type(English)	Outline

Outline

In this thesis, a series of researches, including contact materials, contacts structure configurations, circuit parameter optimizations, and an opening mechanism, were taken to develop a hybrid DC switch that has a low on-state contact resistance lower than 0.6 mΩ and an ability to commutate a 500-A current without arc generations at the same time. The detailed conclusions of every chapter are shown as the followings,

Chapter 1 Introduction

A comparison between the conventional DC switching techniques and hybrid DC switching was made, and it illustrates the importance to develop the hybrid DC switching technologies. Next, the advantages and principles of arc-less current commutation were introduced. How some electric phenomena impact the performance of arc-less hybrid DC switches were also presented, and the research purposes of the thesis are to improve the performance of arc-less hybrid DC switches by utilizing the electric contact phenomena.

Chapter 2 Background literatures of hybrid DC switch and its related electric contact phenomena

By taking other researches as references, including the topologies of hybrid DC switches, the power devices used in hybrid DC switches, and the electric contact phenomena. It was determined to develop a hybrid DC switch by using a ZVS topology and a SiC-MOSFET as the power device. In addition, this research also studied materials, and electric, thermal, solid mechanics, microfluid fields to improve the performance of the proposed hybrid DC switch, based on the related findings in other previous studies.

Chapter 3 Experimental Methodology and Setups

We introduced the components used in this research, consisting of contacts of the different materials (copper, tungsten, and Cu-W clad) and different diameters, and the power device (SiC-MOSFET) and its driving circuit. The structures of both circuit and mechanism are also demonstrated in this chapter. In addition, we also illustrate the experimental methodology and measurement equipment, such as oscilloscope, LCR meter, laser sensor, SEM, and so on.

Chapter 4 Realization of Arc-less Commutation with Copper, Tungsten, and Bridge-type Contacts in a Hybrid DC Switch

It was found there are three methods used to improve the threshold current of arc-less current commutation. One is to reduce the effect of the additional over-voltage caused by the current commutation path, which is realized by using a lower separation speed and a shorter current commutation cable. Another one is to generate a more stable molten bridge between the contacts, for example, by using large contacts to change the contact surface condition in the stationary contact stage. The last one is to increase the boiling voltage or theoretical equivalent boiling voltage of contacts, which are always achieved by using a suitable contact material and utilizing a multi-pole contact system.

Chapter 5 Optimization of the Hybrid DC Switches by Using Copper-Tungsten Clad Contacts in a Hybrid DC Switch

New-type Cu-W clad contacts were proposed. Through experiments, it was certificated the new-type Cu-W clad contacts have a low on-state contact resistance, which is almost as low as the one of copper contacts. As for current commutation characteristics, the Cu-W clad contacts are able to commutate a 600-A current into the SiC-MOSFET without any arc generation if the tungsten top layers are thin or the diameters of contacts are large. However, for copper contacts and tungsten contacts, their threshold currents of arc-less current commutation are only 120 A and 200 A, respectively.

Chapter 6 Multi-physics Simulation of Thermal Equilibrium of Molten Bridge in a Hybrid DC Switch with Arc-less Commutation

A 2D symmetric model of a molten bridge was established by coupling the mechanical, electrical, thermal, and fluidic physics in COMSOL software. The models of stationary contact, contact force releasing, and phase change stages verified the classical 'a spot' and 'static and dynamic molten bridges' theory, and also revealed the essential physics of some abnormal phenomena, such as the fluctuations of contact voltages at the melting voltage. The results of the simulations coincide with the experiment data, and also verify the theories of some literatures. They are useful for us to understand the softening and melting phenomena of electric contact.

Chapter 7 Conclusions

A summary of the whole thesis was made. Future works were also introduced, including a thermal simulation of SiC-MOSFETs, studies on the behaviors of varistors, development of an advanced mechanism, and also an optimization of the simulations of hybrid DC switches.