LABORATOIRE PLASMA ET CONVERSION D'ENERGIE
UMR 5213

PhD Thesis position

Workplace :

Laboratory of Plasma and Energy Conversion - UMR CNRS 5213.

Toulouse - Occitania – France.

Title :

Design of architectured metallized ceramic substrates for the voltage rating rise of power modules for medium-voltage power electronics applications.

Key words :

Insulating dielectric materials, high voltage, ceramic substrate, power module, electrical characterization, numerical simulation, partial discharges, dielectric breakdown, physical mechanisms

Position's description

General background

The thesis work is part of the Franco-German project "ARCHIVE" (for ARchitectured Ceramic for HIgh power Electronics), supported by the French A.N.R. and the German B.M.B.F. agencies.

The ceramic substrate is indeed at the heart of this project's concerns. It is, in the standard packaging technology of today's power modules used in power electronics systems, the element that leads to a severe compromise between electrical insulation and heat dissipation performance. This compromise is such that it is an obstacle to the rise in the voltage rating of these power modules above 10 kV.

The technical solutions considered in ARCHIVE are based on a ceramic substrate with a specific design of its both sides, combining simultaneously the clever distribution of the electrical stress on the insulating materials (reduction of electric field reinforcements on the front side), and a better thermal cooling (on the back side) by a dielectric fluid.

ARCHIVE will also present a final demonstrator in the form of a complete module, integrating the proposed new ceramic substrate concept sized for 20 kV-semiconductor dies (as some laboratories already have, based on silicon carbide technology). Its performances will illustrate the advantages of this solution, especially for applications such as HVDC (High Voltage Direct Current transmission network of electrical energy), where it would offer a spectacular simplification of the global system (from hundreds of power modules currently to a few dozen).

Partnership and research group presentation

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The contribution of Laplace laboratory to ARCHIVE project, and in particular that of the doctoral student, concerns the "electrical insulation" part. The heat dissipation part is the responsibility of the University of Kempten (Germany), Supergrid Institute (France) is involved in the specification and realization of the final demonstrator, and Ceramtec Gmbh (Germany) will develop and manufacture the ceramic parts necessary for the studies to be conducted and for the demonstrator.

The doctoral student will be part of the MDCE research group (Dielectric Materials in Energy Conversion group) at Laplace. MDCE group is specialized in the field of high voltage insulating dielectric materials, including those used in the environment of the semiconductor chips (in Si, or SiC) of power components. Two previous studies (Hélène Hourdequin, University Paul Sabatier Toulouse III, PhD thesis, 2018; and Hugo Reynes, I.N.S.A. Lyon, PhD thesis, 2018), dedicated to the study of new concepts of metallized insulating ceramic substrates in order to adapt them to the rise in voltage withstanding of new semiconductor chips (> 20 kV today), will form the basis of the research conducted as part of the proposed thesis.

Purpose of the thesis work

The aim is to study and design an insulation system based on an optimized metallized ceramic substrate architecture, in order to allow the elaboration and demonstration of a medium-voltage (20 kV) power module.

The work is founded on a global approach of the design, including a comprehensive study of the underlying physical mechanisms limiting the performance under high voltage, numerical simulations for electrical performance analysis and for design, elaboration of test-structures, and experimental characterizations of test-structures and 'ARCHIVE metallized ceramic substrate' prototypes.

Description of the thesis work

The work during the thesis focuses on the study of the high voltage metallized ceramic substrate of the power module, and it is based on a broad scientific approach linking different types of activities:

- understanding study of the physical mechanisms and parameters, intrinsic or extrinsic, leading to the insulating system degradation under high voltage, using reference-test-structures (this part is more relevant to the physics of electrical insulation systems, in correlation with numerical simulation results and experimental physical characterizations)
- study and design of innovative "high voltage" metallized substrate structures, integrating the physical but also the technological constraints (this part will use numerical simulation tools)
- development of elementary structures dedicated to experimental studies for understanding and evaluating the specific high voltage behavior of metallized ceramic substrates (under an extended voltage range above 10 kV),
- experimental characterizations, as electrical tests (breakdown electric field, partial discharge inception voltage) under high voltage supply (>> 10 kV), and other correlated physical characterizations (optical, physicochemical, structural), of the structure or the constitutive insulating materials.

These activities will be of course preceded by an initial bibliographic work on the state of the art in terms of packaging of high voltage power modules, and research issues raised by the desired improvement in their ability to operate sustainably under voltage levels that are well above current standards.

The ARCHIVE project framework (in particular through the involvement of a partner developer/supplier of ceramic substrates, and a designer/user of very high power modules), was built to allow the foreseen design global approach and to succeed in the completion of the targeted insulation system and 20 kV power module demonstrator.

Start date :

01/01/2020

Funding details :

Under contract with Paul Sabatier University, in the frame of a project funded by the Research National Agency (A.N.R)

Institution and Laboratory presentations

Toulouse III – Paul Sabatier University
With its roots dating back to the 13th century, Toulouse III - Paul Sabatier University was officially founded in 1969 following the merger of the faculties of medicine, pharmacy and science. The diversity of its laboratories and the quality of its courses in the fields of science, health, sport, technology and engineering have guaranteed its scientific influence over the last fifty years and have made it one of the best universities in the world. In 2017, it was ranked among the 300 best establishments for scientific performance in the international ARWU ranking.

Education at Toulouse III – Paul Sabatier University in a few key figures:

- 31 723 students (in 20162017)
- 13 bachelor degree disciplines
- 44 vocational Bachelor degrees
- 22 DUTs (Technical University Diplomas)
- 29 Master's disciplines,
- 95,2% of graduates on the job market are in employment 30 months after receiving their Master's.

At Toulouse III - Paul Sabatier University research is organised into five committees : Materials Sciences ; Mathematics, Information and Engineering Sciences and Technologies ; Universe, Planets, Space, Environment; Biology, Agronomy, Biotechnology, Health ; Human & Social Sciences.

Research at Toulouse III – Paul Sabatier University in a few key figures:

- 68 laboratories and shared facilities
- 11 doctoral schools
- 1710 PhD students (in 20172018)
- 430 defended PhD (in 2016)
- 2509 teachers end teachersresearchers.

Laboratory Plasma and Energy Conversion Laboratory (Laplace)
Laplace laboratory's researches weave an "activity continuum" encompassing the production, the transportation, the management, the conversion and the use of the electricity while covering all the aspects right from the study of fundamental processes in solid and gas to the development of processes and systems. Within this widespread field, the major themes concern the plasma discharges as well as plasma applications, the study of the dielectric materials (polymers, in particular) and their integration into the systems, the study and the design of the electrical systems, the optimization of the control and the power converters.

The research topics by their multidisciplinary nature lean on a physical science base willing to study the basic phenomena and introduce new concepts emanating from the fundamental sciences but, evidently, strongly motivated by the constraints and the technological or the environmental locks; they are therefore linked to the industrial activities through various collaborations and participate in the transfer of technologies, especially in the aeronautic domain.

Because of its human potential, Laplace is the first French concentration of research in the field of Electrical Engineering and Plasma nationally with 160 fulltime researchers and a similar number of PhD students and postdocs.

Web site :

http://www.laplace.univ-tlse.fr

Candidate profile's

The candidate will hold research master's degree (or equivalent) in the fields of Engineering Science, or Electrical Engineering. Skill in the following disciplines will be highly appreciated : Physics of Dielectric Insulating Materials, Physics of Insulation Systems, Power Electronics.

Autonomy, critical thinking, ability to work in a team, and the ability to integrate into a multi-partner project will be a plus for this position.

Date limite de candidature

30/11/2019

Documents to provide

Please send CV, cover letter, school transcript and letters of reference