Post-doctoral grant

Optimization of the synthesis and shaping parameters of multifunctional oxide ceramics for the design of an integrated packaging of a power electronic module

Position start: to be defined (possibly until March 2024)

Coaching Consortium

• Paul-Etienne VIDAL – University Professor (Chairholder), e-ACE2 team of the Production Engineering Laboratory of the National School of Engineers of Tarbes, France.
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• Sophie Guillemet-Fritsch, CNRS Senior Researcher, « Mixed Valence Oxide » team, CIRIMAT – Toulouse, France
• Pascal Dufour, Lecturer, « Mixed Valence Oxide » team, CIRIMAT – University Paul Sabatier Toulouse, France.

Important dates

• Opening of applications: December, 07th 2023
• End of applications: January, 09th 2024 - 6pm
• After a selection phase on file, interview by video (or face-to-face) will be held by invitation between January, 10th 2024 and January, 12th 2024.

Introduction

In the field of electrical energy conversion, the energy efficiency of these devices is at the heart of the strategies for developing products and services for the coming energy transition. In particular, in the field of transport, the constraints induced by this transition direct research activities towards the design of static converters in new forms, or the use of new materials and processes that make them more efficient or more effective. In the aeronautical field, the most significant constraint is the relationship of electrical power converted to volume and mass of the device, which tends to the development of high-power devices in restricted volumes.

The proposed research work aims to continue the investigations carried out during Romain Raisson's thesis (defended in November 2023), relating to functionalized ceramics, showing property's gradient, with the aim to integrate then into the assembly of power electronics, and more particularly as a metallized ceramic substrate. The work of the post-doctoral student will consist in improving the shaping parameters for obtaining a ceramic-metal pellet, multifunctional, of complex shape, in carrying out electro-thermomechanical characterization of the ceramics and the assembly, and to optimize the electrical and thermal properties of this multifunctional ceramic.

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Previous work

The team of the LGP laboratory is working on the development of more efficient power electronics assembly processes. The work focuses on the modeling [1] and the integration into the assemblies of conversion architectures, geometries and component technologies in order to improve the energy efficiency of the conversion function [2].

The team of the CIRIMAT laboratory has a long experience in the synthesis of powders, and their shaping. In the "Mixed Valence Oxides" team, different types of passive components (varistors, capacitors), thin semiconductor films and substrates have been developed and studied, by modifying the chemical composition and/or their shaping, in order to increase their performance [3-5].

Scientific objective

The aim of this project is to optimize the synthesis and shaping parameters of multifunctional ceramics, in order to obtain more interesting electrical and thermomechanical properties, as well as complex geometries.

Scientific and technological issues

The first scientific challenge concerns the identification of the parameters that allow, after synthesis and shaping by SPS, to obtain a multifunctional ceramic with optimized properties. The corresponding technological challenge consists in developing experimental protocols which make it possible to obtain multifunctional ceramics with optimized properties.

The second scientific challenge is to establish the experimental protocol that allows, by co-sintering, to obtain a multifunctional ceramic with a complex shape. It may be a ceramic obtained in a single operation, or several ceramics with complex shapes which, by assembly, will give the final shape. The associated technological challenge is the application of this protocol, obtaining multifunctional ceramics with a complex shape. The second associated technological challenge is the production of a power assembly from this complex shape, and its electrical and thermal characterization.

Work plan

After analyzing and studying the preliminary work and the associated state of the art, the post-doctoral will plan a phase of reproduction of the assemblies in order to completely assimilate our state of knowledge. In a second phase, the important parameters of synthesis and shaping by SPS of multifunctional ceramics, will be adjusted in order to obtain optimized properties. As a matter of facts, the tasks will be:

1. Maximize the heat dissipation coefficient,
2. Maximize (or optimize) the value of the capacitance by acting both on the permittivity and loss values as well as on the geometry of the pads,
3. Maximize the dielectric withstand value (breakdown field).
4. Minimize the thicknesses of ceramic materials while guaranteeing a certain mechanical strength,
5. Maintain the thick layers of metal, possibly with an innovation proposal to develop thick copper metallizations.

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The third phase of the work will consist in obtaining complex shapes from multifunctional ceramics with optimized properties, and their implementation within a power assembly. The assembly thus obtained will give rise to a characterization phase through various experiments, including electrical characterizations in representative environments such as the double pulse test bench, for example.

During this work, the post-doctoral may be a source of proposals in the scientific and technological choices in line with the initial specifications, and in his proposals for communications and valuation of the work.

Literature data

[1]. M D. Kenfaui, M.L. Locatelli, Z. Valdez-Nava, L. Laudebat, V. Bley, P. Dufour, C. Tenailleau, S. Guillemet-Fritsch (2019). « Procédé de fabrication d'une pièce composite à matrice céramique, pièce composite, et composant électrique correspondant » demande de brevet français déposée le 23/01/2019, numéro de dépôt : FR1900583.

[2]. S. Dupuis, S. Sulekar, Ji H. Kim, H. Han, P. Dufour, C. Tenailleau, J.C. Nino, S. Guillemet-Fritsch. "Colossal permittivity and low losses in Ba1-xSrxTiO3- reduced nanoceramics". Journal of the European Ceramic Society 36 (2016) 567-575

[3]. C. Clavel, "Démonstrateur de faisabilité d'un condensateur fonctionnalisé pour applications en électronique de puissance", rapport de Master MECTS, Université Toulouse III, Juin 2019.

[4]. R.Raisson, " Développement d'un condensateur céramique fonctionnalisé pour application en électronique de puissance", stage de Master 2 Matériaux : Elaboration, Caractérisation et Traitements de Surface Mention "Sciences et Génie des Matériaux", Université Toulouse III, février 2020- juin 2020SDJ

[5]. R. Raisson, S. Guillemet-Fritsch, P. Dufour, P.-E. Vidal, Assemblage céramique métal aux propriétés électriques hétérogènes, Journées Annuelles du Groupe Français de la céramique, Albi, 21 mars 2022,

[6]. R. Raisson, S. Guillemet-Fritsch, P. Dufour, P.-E. Vidal, Development of a Functionally Graded Capacitor by SPS, International Ceramic Conference (ICC9) and the Electroceramics XVIII conference, Krakow, Poland, 10 - 14 July 2022,

[7]. R. Raisson, S. Guillemet-Fritsch, P. Dufour, P.-E. Vidal, Condensateurs à gradient de composition BaTiO3-Ni pour des applications en Electronique de Puissance, Conférence internationale Matériaux Lille 2022, 24-27 octobre 2022,

Profile

The candidate must hold a doctorate in "materials" "materials science" or equivalent specialty, obtained recently. He (she) must be able to prove experience in the field of technical ceramics, through his thesis research subject, his practical internships during his training course, and by any experience that can demonstrate knowledge. theoretical, practical, etc. in all the phases of elaboration and characterization of a ceramic.

The candidate will join a very dynamic project team, made up of researchers, teacher-researchers, doctoral students and industrial research engineers. Collaborative work and scientific exchanges are numerous, both face-to-face and remotely. An application which demonstrates a similar work environment will be appreciated. Many experimental manipulations are to be expected, the most obvious being: chemical synthesis, Spark Plasma Sintering, characterizations: SEM – X-ray – diffractometry – granulometry – electrical (impedance analyzer), etc.. In case of several applicants, the number of known and mastered techniques will become a selection criteria.

The candidate must also have a good level of command of English and the qualities of written and oral communication and synthesis, in French and in English. Indeed, a detailed progress report is required during the four-monthly scientific committees and the annual steering committees.

Location of the post-doctorate position

In Toulouse, the work will largely take place at CIRIMAT

• Paul Sabatier University, CIRIMAT building, 118 route de Narbonne 31062 Toulouse.

During stays in Tarbes, the work will take place at 2 sites located 5 km from each other:

• Production Engineering Laboratory, National School of Engineers of TARBES, 47 Avenue d'AZEREIX, 65000 TARBES;

• PRIMES platform, 67 Boulevard Pierre Renaudet, 65000 Tarbes. This address will be the main location of the study.

Funding

This subject is part of a partnership project involving three universities or institutes, and two industrials (the senior partnership chair EFICIENCE, E2S-UPPA PIA-ANR-16-IDEX-0002).

The post-doctoral student will receive funding from the University of Pau and Pays de l'Adour (UPPA) for a period of 12 months. A few hours of teaching will be carried out (64 hours tutorial per year) at ENIT.

Supporting documents to be provided:

At the time of the application, the candidate must imperatively provide:

• Curriculum vitae
•Cover letter
• PhD defense report, with the thesis reports made by reviewers
• Contact details of the thesis supervision team (director, co-director and supervisors).

The candidate may provide one or more letters of recommendation at his or her convenience.

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