Post-Doctoral Position
Oct 2025-Sept 2026 (12 months)

Title: Surface chemical grafting of magnetic nanoparticles on thermal conductive 2D particles for heat management in electronic integrated systems

Background:

The three-dimensional (3D) integration and downsizing of the new generation of power electronic systems, combined with more severe stresses (electrical, thermal, mechanical) in working conditions of power devices, impose stringent requirements in terms of packaging materials to ensure their long lifetime and reliability [1]. High thermal conductivity, electrical insulating, and low coefficient of thermal expansion (CTE) polymer composites are usually in great need in order to efficiently spread the cumulative heat during operating conditions to avoid reaching the thermal runaway conditions of the power devices. To facilitate the heat dissipation and relieve the thermal stress, polymer-based composites that include ceramic platelet-shaped particles (e.g., BN, AlN) with enhanced thermal conduction are usually involved instead of pure polymers with low conductivity (~0.2 W/mK) [2, 3]. However, the random dispersion of the particles limits the thermal conductivity improvement of the composites to few units of W/mK only, even for very large filler contents >30 vol% resulting in the loss of processablity and leading to mechanical stiffness incompatibilities [2, 3]. To overcome this issue, researches have successfully attempted to improve the thermal conductivity by orientating the platelets in composites in one specific direction to create an anisotropic path for the heat extraction. Among the various approaches, magnetic alignment is very attractive in this regard due to the remote control of filler alignment and possibility of orienting filler at arbitrary directions [4]. Magnetic alignment requires the filler to respond to an external magnetic field. Although thermal conductive 2D materials (like *h*-BN, graphene) are not intrinsically magnetic responsive, they can become subsequently functionalized by a surface 'decoration' with magnetically-responsive nanoparticles. The growth or attachment of magnetic nanoparticles to *h*-BN surface can be achieved by surfaces by hydrolysis of an aqueous solution containing iron salts or through the intermediate of chemical ligand grafting [5].

Objectives:

The objective of this post-doctoral position is to develop a process for the surface decoration of thermal conductive 2D materials (*h*-BN, graphene, rGO) with grafted magnetic nanoparticles or a growth magnetic shell (e.g., Fe_2O_3, Fe_3O_4, Mn_2O_3, Mn_3O_4). The postdoc fellow will propose and take care of the chemical functionalization process development to grow or attach nanoparticles onto the 2D material surface. In addition, s/he will characterize the quality of the surface decoration (distribution, size, thickness) by the means of different techniques such as FTIR, XRD, SEM, TEM EDX, AFM. Finally, the postdoc fellow will also evaluate the magnetic response of the decorated platelets at the local scale by using the magnetic mode of AFM and at the macroscopic scale by magnetometry.

Profile of the applicant:

PhD in material science or in chemistry is required with skills in material synthesis, nanoparticle functionalization, colloids, and in material characterization are be highly appreciated.

The strong experimental character of this proposal will require to apprehend and perform numerous experiments and characterizations. The postdoc fellow will be part of a multidisciplinary project: curiosity, openness of mind towards material sciences and engineering applications is required. A proficient English level (C1, C2) is required to favour scientific diffusion.

Place of work:

The postdoc fellow will develop her/his activity at the LAPLACE Institute, within the MDCE research group, located on the site of the University of Toulouse (UT campus), Toulouse, France.

About the host:

The LAPLACE Institute, in the University of Toulouse, is the largest French Research Institute in the field of Electrical Engineering with 300 staffs. It seeks 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, ceramics, composites 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.

The Dielectric Materials in Energy Conversion group (MDCE) conducts research on insulating and dielectric materials and 3D integration technologies for electrical energy conversion. This work is driven by a strong need to reduce the volume and mass of energy conversion systems, as well as their losses. This need, in practice, leads to a desire to increase voltage levels and power density, reduce dimensions, and use new so-called "wide bandgap" components. Some of these devices are also required to operate under new and severe conditions, such as low pressure, high temperature, or very high voltage. In this context, the MDCE group develops polymer/ceramic composite materials with advanced functionalities (electrical, thermal, mechanical) for enhancing electrical system efficiency when they operate at high voltage.

This postdoctoral position is part of a new research program funded by the French research funding agency (ANR), which has started in 2025, and that intends to develop novel polymer-based composite materials to improve the thermal management of integrated electronic systems.

Period and Salary:

The postdoctoral position starts on October 01, 2025 and ends on September 30, 2026 (12 months in total).
Gross salary: 34 k€/year before income tax.

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Application deadline: **July 31, 2025**.

References of related works:

[1] M. Liu, A. Coppola, M. Alvi, and M. Anwar, Comprehensive Review and State of Development of Double-Sided Cooled Package Technology for Automotive Power Modules, IEEE Open Journal of Power Electronics 3(2), 271-289, 2022.
[2] Yongcun Zhou, Yagang Yao, Chia-Yun Chen, Kyoungsik Moon, Hong Wang and Ching-ping Wong, The use of polyimide-modified aluminum nitride fillers in AlN@PI/Epoxy composites with enhanced thermal conductivity for electronic encapsulation, Scientific Reports 4, 4779, 2014.
[3] Zengbin Wang, Tomonori Iizuka, Masahiro Kozako, Yoshimichi Ohki and Toshikatsu Tanaka, Development of Epoxy/BN Composites with High Thermal Conductivity and Sufficient Dielectric Breakdown Strength Part I -Sample Preparations and Thermal Conductivity, IEEE Transactions on Dielectrics and Electrical Insulation Vol. 18(6), 1963-1972, 2011.
[4] Ziyin Lin, Yan Liu, Sathyanarayanan Raghavan, Kyoung-sik Moon, Suresh K. Sitaraman, and Ching-ping Wong, Magnetic Alignment of Hexagonal Boron Nitride Platelets in Polymer Matrix: Toward High Performance Anisotropic Polymer Composites for Electronic Encapsulation, ACS Appl. Mater. Interfaces 5, 7633−7640, 2013.
[5] Ho Sun Lim, Jin Woo Oh, So Yeon Kim, Myong-Jae Yoo, Seong-Dae Park, and Woo Sung Lee, Anisotropically Alignable Magnetic Boron Nitride Platelets Decorated with Iron Oxide Nanoparticles, Chem. Mater. 25, 3315−3319, 2013.