TITLE

Development of new composite materials using 3D printing: contribution of rheology to the study of 3D printability criteria for microwave electronics applications

LAB & PEOPLE

- **Name of the hosting lab:** IRDL UMR CNRS 6027
  General activities of the lab: engineering of materials (composites, nanocomposites, biocomposites; multi-material assemblies; material behaviour and durability; energy systems and thermal processes; structures, fluids and interactions) and systems used in industrial sectors related to the automobile, energy, aeronautics, health and transport industries and more specifically to all fields with a dynamic interaction with the marine environment (shipbuilding and offshore construction, marine energies).
  Website: https://www.irdl.fr/dupuy-de-lome-research-institute/
  Number of staff / PhD: 110 professors and assistant professors, 55 engineers, technicians and administrative staff, 135 phD students and postdoctoral researchers, totalling about 300 members.
- **Supervisor name and contact:** Julien VILLE (Full Professor), julien.ville@univ-brest.fr

TOPIC OF THE INTERSHIP

- Scientific context of the internship (max 20 lines)

The increase in the use of wireless technologies leads to a significant diversification of applications concerning electromagnetic waves emission and, consequently, the need to design and produce absorbing composites. Nowadays, absorbents are not only used to improve the stealth of military systems but also to control interferences inside more and more compact modules [1-3]. Besides, new technologies of composite materials preparation must be used in order to facilitate manufacturing and limit production costs [4, 5].
In this context, the elaboration of innovative absorbent composite materials appears as a potential and remarkable development of additive manufacturing techniques such as 3D printing by fused deposition modelling. This technique requires the use of a composite available as filament. However, in the case of magnetic composites, ferromagnetic or ferrimagnetic particles tend to make the filament brittle and difficult to extrude. That's the reason why the formulation of a good compromise between processability, 3D printability and electromagnetic performances, appears as a key parameter. Impact of particles geometry and matrix composition have been investigated previously and one of the main results is an empiric power law between relative viscosity and permeability with exponents strongly dependent on particles aspect ratio. Then, the development of composite filaments from a laboratory scale

to a semi-industrial one and the adaptation of the fused deposition modelling 3D printing process are now considered.

Keywords: composite materials, structure, rheology, microwave electronics, 3D printing.

Bibliography:

[1] Grant PS, Castles F, Lei Q, Wang Y, Janurudin JM, Isakov D, Speller S, Dancer C, Grovenor CRM. Manufacture of electrical and magnetic graded and anisotropic materials for novel manipulations of microwaves. Philosophical Trans. A 2016; 373: 20140353.1-20140353.14.

[2] Wang Y, Castles F, Grant PS. 3D printing of NiZn ferrite/ABS magnetic composites for electromagnetic devices. In: Proceedings of Materials Research Society Spring Meeting, San Francisco, April, 2015.

[3] Arbaoui Y, Laur V, Maalouf A, Queffelec P. 3D printing for microwave: materials characterization and application in the field of absorbers. In: Proceedings of the IEEE International Microwave Symposium, Phoenix, 2015.

[4] Arbaoui Y, Agaciak P, Chevalier A, Laur V, Maalouf A, Ville J, Roquefort P, Aubry T. 3D printed ferromagnetic composites for microwave applications. Journal of Materials Science, 4988-4996 (2017).

[5] Vong C, Chevalier A, Maalouf A, Ville J, Rosnarho JF, Laur V. Manufacturing of Magnetic Composite Flexible Filament and Optimization of a 3D Printed Wideband Electromagnetic Multilayer Absorber in X-Ku Frequency Bands, Materials, 15, 3320 (2022).

- Tasks and duties entrusted to the student:

The first part of the internship is essentially experimental. The main objective is to better control the formulation of composite materials and all the steps of the elaboration process (extrusion), filament preparation and 3D printing. Then, the aim consists in obtaining functional composite objects with complex geometries. Linear and non-linear rheological as well as structural properties will be characterized. The investigation of materials-structure-rheology relationships leads to the determination of 3D printability criteria. Electromagnetic performances (permeability, permeability) will be characterized at each step of samples preparation.
In a second step, after adaptation of additive manufacturing technique (with magnetic field along the printing nozzle), 3D printing of complex geometries will lead to objects with increased electromagnetic performances in order to validate optimized efficiency.

- Skills to be acquired or developed:

The student will strengthen his skills in materials engineering: elaboration (extrusion), filament preparation and 3D printing; characterizations (scanning electron and confocal microscopy, rheology, electromagnetism). Besides, the student will be initiated to instrumentation (3D printer equipment) and electromagnetism modelling.

PROFILE OF THE DESIRED STUDENT

Minimum level of study required: Master degree.
Field(s) of study: additive manufacturing, materials engineering, electronics and microwave.
Scientific skills: functional materials characterizations (microscopy, electromagnetism and more weakly rheology), 3D printing (fused deposition modelling).
Language skills required: English.

THE INTERNSHIP ASSIGNMENT:

Desired duration of the internship (in months): 5 months.
Desired Starting date of the mission: February 2024.
Indicative weekly schedule: 35h/week.
Remuneration: 600€/month, paid on national SEA-EU funds for a maximum of 5 months ; additional Erasmus grant could be asked to your own university.
Internship agreement: an internship agreement will be signed.

To SEA-EU students:
If you're interested please send your CV and letter of motivation to the scientist in charge, julien.ville@univ-brest.fr before November, 1st, 2023.