ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

Microwave characterization and applications of emerging carbon based materials (graphene, biochar) as filler in film and composites.

Funded By	Dipartimento DET
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Context of the research activity	The research will be aimed at investigating the electromagnetic properties of emerging carbon based materials, such as graphene and biochar, and their applications at microwave frequency. Carbon based materials can be used as filler for film deposition or in composites. The most promising field of application will be taken into account, ranging from gas, humidity or bio sensors to tunable devices. A parallel analysis will take into account shielding properties of the cited emerging materials.
	In recent years, carbon based materials have been gaining attention for their potential as filler in film deposition or in composites based on polymers, concrete, or drywall panels. The electrical and mechanical properties of these types of materials can be tuned using different percentages and different kinds of fillers: either low cost (e.g. carbon black), eco-friendly (e.g. biochar) or sophisticated (e.g. graphene). Moreover, graphene, carbon nanotubes and biochar have been used as fillers to produce highly conductive composites. The conductivity values need to be considered in combination with a number of other factors including mechanical robustness, ease of fabrication, cost and environmental impact. Graphene, a 2D structure with carbon atoms arranged in a hexagonal (honeycomb) lattice, exhibits intriguing mechanical, thermal and electrical properties.. Films loaded with graphene have gained a large amount of interest for many applications in the optical range, and for RF and millimeter applications, humidity sensors, glucose sensors, components, and flexible electronics. However, there has been little research done on the characterization of graphene films at microwave frequencies, making it difficult to retrieve adequate electromagnetic models. Graphene conductivity can be computed using the Kubo formula in the case of pure graphene only. In this case, the surface conductivity is almost constant up to 10 GHz and can be modeled as a resistance. Films loaded by graphene flakes can be deposited on different substrates with a screen printing technique through the preparation of inks with a proper combination

Objectives	of solvents and binders. Dealing with graphene films made of different chemical components, in order to keep into account all the substances present in the ink, a customized model will be introduced. A theoretical, simulation and experimental activity will be performed considering several microwave devices to obtain and compare the various models. Furthermore, the problem of taking into account in the model the effect of applied voltage will be addressed. Such an improvement could be exploited for more sophisticated applications like RF controllable and tunable devices. The equivalent lumped circuit model will be the starting point towards the full-wave electromagnetic modeling and analysis of graphene loaded microwave structures intended for sensing and tuning applications. In addition, among the other carbon based materials used at microwave frequency, eco-friendly materials as biochar will be considered. Biochar is cheap, readily available and environmentally friendly and thus is a very good contender among other carbon-based materials for various applications. Conventional fillers used in composites are metals, which are heavy and expensive. Carbon based fillers like graphene and carbon nanotubes are expensive and involve chemical processing including the use of harsh chemicals and petroleum based materials that are not sustainable. Biochar is less conductive as compared to its competitors but It has been demonstrated that a thermally treated biochar is more conductive and thus suitable for many applications. There has been an increasing amount of work performed on electromagnetic interference (EMI) shielding materials due to increased use of electronic and communication equipment in recent years. Drywall panels coated with several layers of biochar paste are low cost and of easy fabrication, and they can offer great flexibility to realize protected environment for health care applications (chemotherapy equipment, tomography) reducing the strong intensity of the electromagnetic fields in the case of nearby electronic equipment or telecommunication repeater. Multi-layer absorbers will be designed in order to obtain absorbers working in a wide frequency band and for different angle of incidence. Coated drywall panels will be realized and the transmission of the electromagnetic waves through the panel measured in an anechoic chamber and compared with the simulated ones.

Skills and competencies for the development of the activity	-Sono richieste per lo svolgimento dell'attività di ricerca proposta: - solide competenze di campi elettromagnetici, microonde, progetto e caratterizzazione di dispositivi a radiofrequenza - software di calcolo: Matlab, PYTHON, C, C++ - software a radiofrequenza: ADS / NI AWR Design Environment / AWR Microwave Office - capacità nell'affrontare nuove discipline ed un ambito di ricerca multidispiplinare