Soft Graphene-Based Antennas for Ultrawideband Wireless Communication

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EXTENDED ABSTRACT

1. Introduction

Ensuring user-friendliness and the seamless integration of technology into the fabric is a key challenge both for academics and industry participants. Thus, textiles that provide a seamless command-oriented user interface [1] and have capable of wireless communication [2] have been an increasingly popular topic in recent years. In the field of textile antennas, patch antennas either with the use of embroidering techniques [3], conductive fabrics [4] or inkjet-printing [5] are leading the way over traditional bulky antennas. However, there are still significant problems in additive antenna fabrication such as the need to use metallic components as the conductive element which quickly becoming corroded and oxidized and also bringing high material costs [6]. The main objective of this study is to develop graphene-based antennas for smart textiles that push the state-of-the-art in wireless body-centric systems, by utilizing traditional textile manufacturing techniques. Hence, this research suggests a graphene-based antenna on a textile substrate, where the conformity of the antenna is highly desirable for the wearable and body-centric applications. The designed antenna consists of a coplanar-waveguide (CPW)-fed planar inverted cone-shaped patch geometry [7], aiming ultrawideband antennas that work in a wide spectrum from 3.1 to 10.6 GHz.

2. Material and Methods

Synthesis of Multilayer Graphene and Transfer Printing of Graphene on Polyethylene Sheets: Multilayer graphene samples were synthesized on 50 µm thick nickel foil substrates using chemical vapor deposition system, by following the protocol proposed by Polat *et. al* [8]. The thickness of ML graphene samples were controlled by the growth temperatures varied between 900 and 1000 °C. The number of graphene layers was approximately 100. A so-called "fishing process" enabled transfer printing of large area ML-graphene with a thickness of 25 µm on porous polyethylene (PE) substrates. ML graphene was detached from the nickel substrate in concentrated $FeCl_3$ solution (1 M), and then it was transferred on the distilled water surface. Porous PE sheet was immersed into a liquid for conformal coating of ML graphene and then dried in an oven at 70 °C for two hours to remove residual water molecules. The sheet resistance of ML-graphene was *c.a* 25 Ω/sq. Fig.1 demonstrates macroscopic assembly of graphene on Ni sheets, and flexible graphene transferred PE sheets.

Fabrication of Graphene-Based Textile Antenna: These self-standing ML-graphene sheets were laminated with insulating glass microfibers nonwoven supplied from Pilkington *Co.* to avoid the possible short-circuiting effect of crinkled graphene edges touching fabric. Then, as illustrated in Fig. 1, these graphene sheets were cut and transferred onto the fabric by heat lamination. This method triggered by applied heat assists bonding between fabric and graphene/PE sheets and provides strong interface. After the transfer printing of ML graphene onto fabric, we used silver-based conductive epoxy (CircuitWorks 2400) to attach connectors. Adhesive copper tapes were placed on top of the fabric for ground connections. As seen in Fig. 2, after trimming the glass microfiber, graphene-based antenna component was invisibly and unobtrusively integrated into fabric.

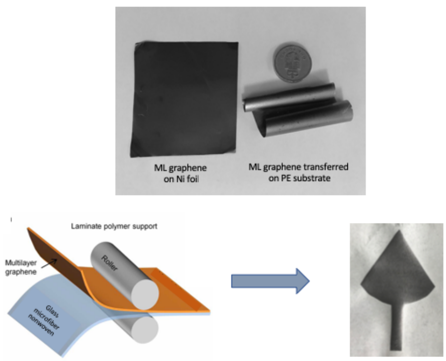

Figure. 1. Images of ML graphene on Ni foils (*top-left*) and flexible ML transferred on porous PE sheets (*top-right*), the illustration of heat lamination method used for heat bonding of glass microfiber nonwovens and fabrics (*bottom-left*), an image of soft graphene-based fabric antenna (*bottom-right*)

3. Results and discussion

The antenna performance was evaluated by numerically and experimentally based on *S*-parameters, radiation pattern, realized gain and efficiency. Numerical simulations and testing of the fabricated prototype demonstrated coherent results. Though some mismatches were observed due to unavoidable fabrication tolerances and real-time losses in characterization, which could not be predicted in simulation. Fig. 2c shows that the simulation covered a whole 2–8 GHz band, while the measurements were taken from the Vector Network Analyser (VNA) illustrated a bandwidth of 2.45–8 GHz. Simulated antenna efficiency was approximately 60% in overall bandwidth. The omnidirectional radiation was observed due to the co-planar structure.

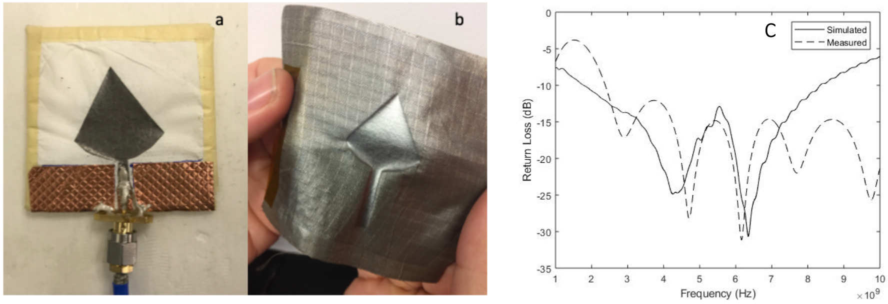

Figure. 2. a) Image of ultra-wideband antenna with ground layer placed on top and b) A prototype revealing invisibly integration of graphene based antenna component into conductive fabric c) Simulated and measured S_{11} of the proposed graphene-based antenna.

4. Conclusion

The proposed antenna covers a bandwidth of 2–8 GHz. The simulated results have shown that the realized gain of the antenna ~3 dBi with the antenna efficiency of ~60 %. The attractive features of conformity, lower design complexity, and fabrication ease, as well as the integration of an environment-friendly and low-cost graphene, have suggested the proposed antenna well suited for body-centric, biomedical and wearable applications.

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