Proceedings of ISAP 2014, Kaohsiung, Taiwan, Dec. 2-5, 2014

Investigation of Embroidery Conductive Layer Dyed with Graphene and ZnO

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Abstract - **This paper presents a method to improve the conductivity of embroidered patch antenna by using graphene and zinc oxide (ZnO) nanopowder. By dispersion and immersion of graphene and ZnO, the embroidered conductive patch layers have been designed, fabricated and tested. Analysis of the effect of graphene and ZnO solution on patch resistance has been carried out. The measured results show that the conductivity performs better with ZnO dyed embroidered patch layer. In contrast, graphene improves the sheet resistance while ethanol solvent reacts with silver thread.**

Index Terms — **embroidery antenna, patch antenna, graphene, zinc oxide.**

I. Introduction

Wearable antenna with garment integration becomes essential nowadays in many applications such as in medical field, military development, mineworker tracking and environment monitoring. These antennas need not only possess good RF performance characteristics but also mechanical structure which is adaptable to conformity and durability [1]-[3]. The wearable antenna needs to be hidden and low profile. Therefore, patch antenna with microstrip feeding is suitable for any wearable application [4].

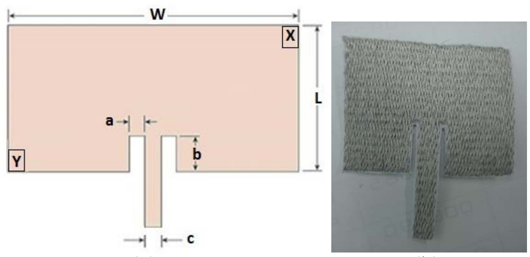
Embroidery patch antenna is a potential candidate that meets the requirements. Furthermore, computerized sewing machine can be used to fabricate textile antennas quickly and on mass manufacturing scales, highly flexible to change the design at minimal costs and time. Researches show that conductivity of embroidered layers can be improved by selecting high conductive thread with more metal concentration, considering stitch direction and spacing between stitches or increasing stitch density, stitch type [5]-[8]. However, these methods have the distinctive disadvantage of increasing stiffness and reducing elasticity. Higher thread friction could also generate excess heat at each of the contact points at high machine speeds and needles damages mainly due to the coarse nature of the conductive threads utilized [9]. As a result of this constraint, the conductivity can be improved by combining the antenna conductive layer with exceptional properties of ZnO or graphene, both of which are in nanostructure powder form.

Graphene is a basic building block for graphitic materials of all other dimensionalities [10]. It has attracted significant attention as a result of its outstanding electronic, mechanical and chemical properties [11]. Meanwhile, ZnO is an important metal oxide nanostructure which has unique advantages in electronic devices, low processing cost, durability and strong energy [12].

This paper reports the initial stage to prepare the embroidery conductive layer for antenna through immersion. For thousands of years, humans have been decorating clothing through immersion of fabrics in liquid dyes [13]. This process provides a useful pathway for incorporating nanopowder into porous, light and flexible embroidered layers which popular spin coating or vacuum coating method cannot achieve.

II. Patch Design and Dyeing Procedure

Fig. 1(a) shows the front view of the patch structure and Fig. 1(b) is the photograph of the patch prototype. The patch parameters are illustrated in Table I.



(a) (b)

TABLE I
PARAMETERS OF CONDUCTIVE PATCH

Parameter	a	b	c	W	L
Value (mm)	2	13	5	49.2925	34.6135

A. *Embroidered Conductive Layers*

The conductive layers have been embroidered by using Shieldex 40-22/7 +110 PET 3ply. The thread lineal resistance is 800 Kohm/m. The conductive thread was embroidered with 2365 stitches and 0.4 mm density on very thin cotton fabric with 0.25 mm thickness. The minimal thickness of the fabric minimizes its effect on the antenna performance and its losses are very small compared to the losses of the sewing thread [14]. The resistances of patch layers were measured using Fluke PM 6304 by choosing the same reference points X, Y as shown in Fig. 1(a).

B. Dispersion and Dyeing Process

Graphene 8nm nanoflakes and 25nm ZnO nanopowder were prepared for dyed solution. According to [11], graphene was observed in the aqueous solution containing 70 vol. % ethanol with maximum concentration of 0.05 mg/mL. while concentration of ZnO in ethanol solvent is 0.5 mg/mL. The solutions were utilized ultrasonic irradiation in sonicating bath for two hours to obtain homogeneous dispersion. The embroidered patch layers were dipped 30 seconds in prepared dyed dispersions then dried for 20 minutes at 70°C. This dyeing process was repeated 5 times and 11 times for graphene, ZnO solution respectively to possess the resistance effect.

III. RESULTS AND DISCUSSIONS

Fig. 2 illustrates the measured resistance results of conductive embroidered antenna patch layer applied graphene and ZnO solution after multiple repeated dyeing process.

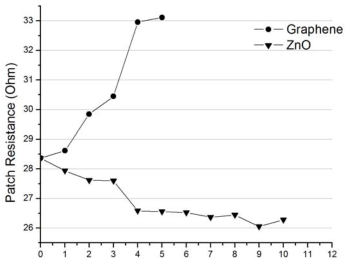


Fig. 2.Resistances of graphene and ZnO dyed antenna patches.

The result shows that ethanol solvent has reacted with silver thread and it causes lost in conductivity. As a result, graphene dyed patch shows the trend to increase in resistivity and graphene solution is therefore not strong enough to enhance the antenna patch conductivity. The graphene dyeing process was stopped after 5 times immersion. In contrast, ZnO dispersion solution helps to increase conductivity up to 7.3% after 10 times dyeing and the ZnO dyed antenna patch seemed to reach its limitation when the average patch resistance achieves at 26.4 Ohm.

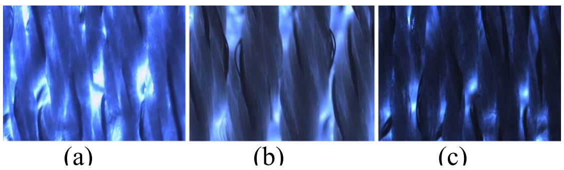


Fig. 3. Microscope zoom 4x view of dyed embroidered antenna patch (a) origin without immersion, (b) ZnO, (c) graphene.

Fig. 3 shows the microscope zoom 4x view of different dyed embroidered antenna patch with ZnO, graphene solutions compared with Fig. 3(a) without immersion under same microscope setting condition. The changing color in Fig. 3 (b), (c) indicates that graphene and ZnO nanopowder were deposited on embroidered surface and the longer time the dyeing process is, the more nanopowder will be placed and the wider gap between threads will be created.

IV. CONCLUSION

In this paper, a new method to improve the conductivity of embroidery patch antenna is introduced. With simple dyeing method, ZnO dispersion solution has improved the conductive characteristic of embroidered patch antenna. Although nanopowder is deposited, the graphene dyed patch raises up sheet resistance because of existing process of ethanol and silver thread reaction. The ZnO dyed embroidered antenna patch will be further integrated with polymer substrate by lamination method to complete a novel class of embroidery antenna with high strength and performance [15].

ACKNOWLEDGEMENT

This research has been supported by Malaysia Government, Ministry of Science, Technology and Innovation (MOSTI), with project no 06-02-12-SF0213.

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