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Experimental Study On Magnetic Shielding Performance Of Al / PET / Rayon Needle Punched Web Under The Exposure To Mobile Phone Field

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Abstract. To obtain the intuitive data of magic field changes with nonwoven metal shielding material, the Al / PET / Rayon needle punched webs was processed with varied parameters, which were position of Al film, mass proportion of Al, needle punched density, and needle punched depth. Magnetic flux density values of Al / PET / Rayon needle punched webs were measured to calculate their magnetic flux density attenuation (MFDA) values under the exposure to mobile phone field. It was found that position of Al film, Al proportion, and needle punched density have a great effect on magnetic flux density attenuation. When Al proportion in needle punched web increases from 10% to 18%, MFDA values increase accordingly, and tend to converge around Al mass ratio 18%. Besides, the promotion range of MFDA values is particularly obvious in the case of needle punched density 50 g m^{-2}. When needle punched density increases from 50 g m^{-2} to 150 g m^{-2}, MFDA values decrease or first increase and then decrease. When needle punched depth rises from 4 mm to 5 mm, the MFDA values of Al/PET/Rayon needle punched webs are almost the same value. Needle punched density and a high mass ratio of Al will contribute to magnetic shielding performance.

1. Introduction

With the wide use of electronic communication devices, the electromagnetic radiation in our lives is increasing. We need to find out an efficient way to reduce the possible damages in common usage of mobile phone. There are many ways to resist electromagnetic radiation, such as metal filament interwoven fabric, metal fibre blended fabric, chemical coated fabric and Nano metal sputter fabric. From the sight of wear ability and easy care, fabrics with electromagnetic conductive material [1-4], such as silver coated filament and stainless-steel fibre, have advantages compared with other fabrics, because conductive and magnetic materials in the yarn form metal meshes on fabric, which makes the electromagnetic energy convert into heat energy and other forms of energy by generating eddy current in the conductor. Accordingly, the electromagnetic shielding fabrics is generally hard-textured and uncomfortable.

Needle punched nonwoven fabric is consolidated by flexible entanglements among fibres, which has uniform and stretchable structures [5]. Besides, needle punching process is short, and costs low, so needle punched material is important in a wide range of consumer products, such as sound box blanket, electric blanket, embroidered material, garment material, handicraft material, leather base cloth and so on. The nonwoven fabrics with conductive fibres can be used as barriers in buildings, an interlining for the clothes and mobile phone envelopes.

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Twenty-first Century has seen a rapid development on mobile phones, as well as other electrical and electronic communication devices. However, it leads to a serious era of electromagnetic radiation pollution. Electromagnetic radiation, known as the "invisible killer" of human beings, cannot be seen and felt, causing great harm to the function of human organs. Along the years, many studies [6-10] have been published on the effect of populations exposing to the mobile phone electromagnetic fields, and electromagnetic shielding materials becomes research hotspots [11-15]. Nowadays many researches have shown that strong magic field have a strong relationship with changes in blood performance and living organisms [16,17]. But there's little literature on the process parameters of needle punched nonwoven magnetic shielding materials. In this paper, we studied structure of Al / PET / Rayon needle-punching material, processed Al / PET / Rayon needle punched webs with varied mass proportion of Al, needle punched density, and needle punched depth, respectively. Magnetic flux density values of Al / PET / Rayon needle punched webs were measured to calculate their magnetic flux density attenuation values under the exposure to mobile phone field. The relationships between needle punching parameters and magnetic shielding properties were analysed.

2. Materials and methods

2.1. Materials

In this paper, we used PET fibre (linear density 6.66 dtex, and staple length 42 mm), rayon fibre (linear density 1.56 dtex, and staple length 39 mm), and Al film (9 g m^{-2}) as materials. PET fibre is used extensively in apparel and home furnishings, which has high tenacity as well as low shrinkage. However, its shortage is low water absorption, which can cause static electricity and sweltering. Thus, we chose rayon fibre to make a fibre mixture for rayon fibre's good performance in water absorption. According to related literature, the performance of electromagnetic shielding has a great relationship with proportion of metal in material [4]. Therefore, from the aspect of raw materials, Al would have a great influence on the electromagnetic shielding performance of needle punched products. Meanwhile, technical parameters in needle punching process, such as needle punched depth and needle punched density, would also affect the performance of the needle punched products. Considering these two aspects, we chose Al percent, needle punched depth and needle punched density as variable parameters, keeping feeding speed and collecting speed fixed. Then the magnetic shielding performance was evaluated and the relationships between magnetic shielding performance and three variable parameters were analysed.

2.2. Methods

2.2.1. Needle Punching Process Experiment

We mixed PET fibre and rayon fibre at the ratio, and fed them into blending machine, carding machine, lapping machine, and pre-needle punching machine in turn. Process parameters of pre-needle punching is fixed. Then Al film was inserted into pre-needle punched webs and fed into punching machine, as shown in Table 1 and Figure 1.

Table 1. Process parameters of needle punching.

Type	Pre-needle punching	Punching	Second punching
Needle punched depth (mm)	4	4,5	4,5
Needle punched density (p cm^{-2})	150	50,100,150	50,100,150
Drafting ratio	1:1	1:1	1:1

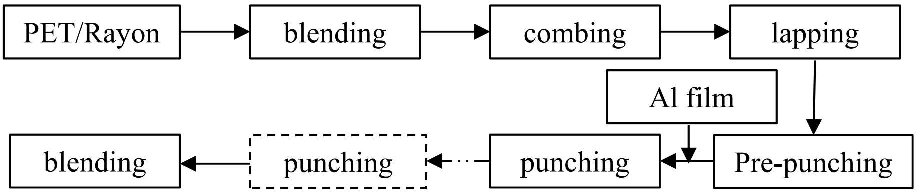


Figure 1. Process of Al / PET / Rayon needle punched web.

2.2.2. Experimental methods
Magnetic flux density was measured for magnetic shielding performance by LZT-1000 Electromagnetic radiation tester (Beijing Longzhentian Electronic Instruments Co., Ltd.). Wrap a mobile phone in each piece of Al / PET / Rayon needle punched web sample, keeping the wrapped mobile phone handset and detecting head of LZT-1000 Electromagnetic radiation tester head to head, while the wrapped mobile phone and LZT-1000 Electromagnetic radiation tester were laid on the same surface, and call the mobile phone. At the same time the phone call is connected, we observed the maximum magnetic flux density value on electromagnetic radiation tester. Each sample was tested 5 times at the same place, and magnetic flux density value $\boldsymbol{B}_n$ was recorded accordingly. The number n is from 1 to N, representing the sample number. We also measured max readouts of magnetic flux density value $\boldsymbol{B}_0$ when a PET/Rayon needle punched web sample took the place of Al / PET / Rayon needle punched web samples.

To obtain the intuitive data of magic field changes with nonwoven metal shielding material, we compared magnetic flux density average value $\boldsymbol{B}_n$ with $\boldsymbol{B}_0$ and obtained magnetic flux density attenuation value MFDA to describe the magnetic shielding properties of materials, which is defined as the following equation:

$$\mathrm{MFDA} = (\boldsymbol{B}_0 - \boldsymbol{B}_n) / \boldsymbol{B}_0 \quad (1)$$

Where $\boldsymbol{B}_0$ is magnetic flux density value without metal shielding material, and $\boldsymbol{B}_n$ is magnetic flux density value with metal shielding material. The n represents the sample number of Al / PET / Rayon needle punched web.

As mentioned above, when we measured magnetic flux density value $\boldsymbol{B}$, the mobile phone handset were set close to detecting head of LZT-1000 Electromagnetic radiation tester head to head, and the wrapped mobile phone and LZT-1000 Electromagnetic radiation tester were laid on the same surface. In this way, $\boldsymbol{B}_0$ and $\boldsymbol{B}_n$ can be seen as the magnetic flux density value $\boldsymbol{B}$ readings in the same direction. Hence, magnetic flux density value $\boldsymbol{B}$ here can be simplified to a scalar B. Then equation (1) can be simplified as

$$\mathrm{MFDA} = (\mathrm{B}_0 - \mathrm{B}_n) / \mathrm{B}_0 \quad (2)$$

As we can seen from equation (2), if a metal shielding material has a high MFDA value, then its magnetic shielding properties is good. And if a metal shielding material has a low MFDA value, then its magnetic shielding properties is poor.

2.2.3. Pre-experiment
The pre-experiment was introduced to determine a suitable structure of Al / PET / Rayon needle-punching material or a proper position of Al film in needle punched web. After mixing PET fibre and rayon fibre by hand in evenness, we fed them into needle punching line, where fibres got blended, combed, laminated and pre-punched into a PET/Rayon pre-punched fibre web at about 55 g m^{-2}. We fold pre-punched web into 4 layers and cut 4-layer web into 3 pieces. Then we inserted 3 layers of Al film into each 4-layer PET/Rayon needle pre-punched fibre web separately, varying the position of Al film in Al / PET / Rayon needle punched web, as shown in Figure 2. We punched each of them twice

and got three different kinds of Al / PET / Rayon needle punched webs' structures. and found that the web hardly possesses magnetic shielding performance when it has the same structure as Figure 2 (a) or (b), but it works with the same structure as Figure 2 (c). Because their magnetic shielding performance was compared with a 4-layer PET/Rayon needle punched web respectively, as shown in Table 2, and showed that only the web with the same structure as Figure 2 (c) indicate a significant difference, while the other show little difference.

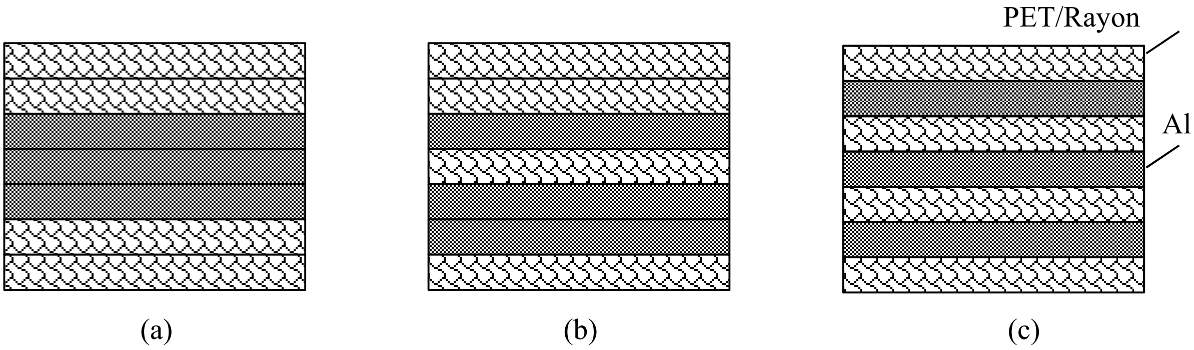


Figure 2. Sketch map of positions of Al film in needle punched webs.

Table 2. Magnetic flux density value of four kinds of needle punched web.

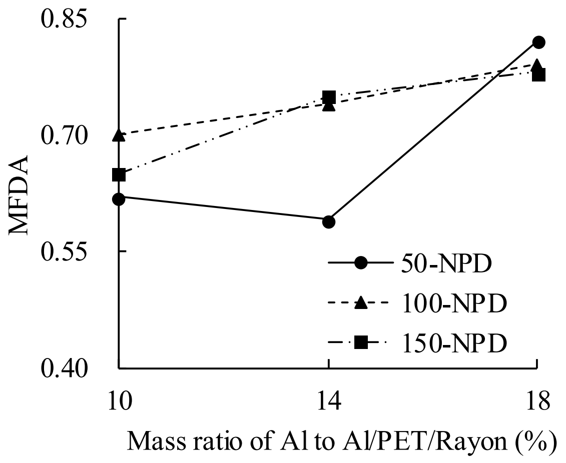
Type	Magnetic flux density ***B*** (μt)					
	1	2	3	4	5	Mean
4-layer PET/Rayon web	18.67	19.06	18.86	19.26	19.14	19.00
Al / PET / Rayon web (a)	18.98	18.62	18.31	18.85	18.91	18.73
Al / PET / Rayon web (b)	17.42	18.13	17.97	18.63	18.10	18.05
Al / PET / Rayon web (c)	4.19	4.34	4.9	5.1	6.51	5.01

3. Result and Discussion

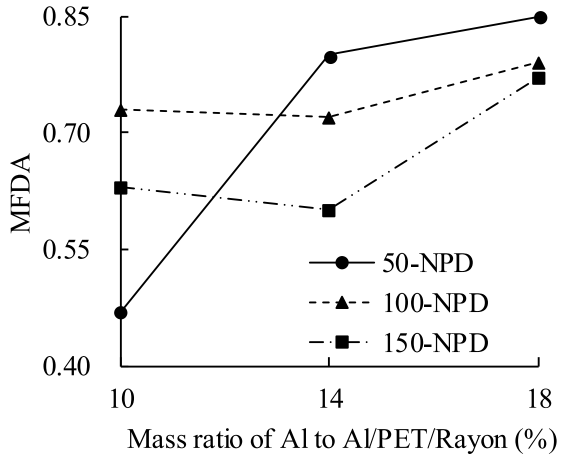
Al / PET / Rayon needle punched webs were processed with verified parameters, such as aluminum proportion, needle punched density, and needle punched depth. The magnetic flux density attenuation MFDA values of Al / PET / Rayon needle punched webs were calculated according equation (1), and the relationships among their magnetic shielding performance and three variable parameters were analyzed as shown in Figure 3, 4 and 5.

3.1. Influence of Al proportion on magnetic shielding performance

As shown in Figure 3 (a) and (b), taking the mass proportion of Al in Al / PET / Rayon needle punched web as the abscissa axis and magnetic flux density attenuation values as the ordinate axis, magnetic shielding performance curve was drawn and the influence of aluminum proportion on magnetic flux density attenuation value was analyzed. Figure 3 indicates that when mass proportion of Al in Al / PET / Rayon needle punched web increases from 10% to 18%, magnetic flux density attenuation values increase accordingly, and tend to converge around Al mass ratio 18%, keeping needle punched depth unchanged. Besides, the promotion range of magnetic flux density attenuation values is particularly obvious in the case of needle punched density of 50 p m^{-2}. It is understood that Al is good electric conductor, therefore a high mass ratio of Al will contribute to a relatively high chance in reducing magnetic flux density. When needle punched density is 50 p m^{-2}, the Al film is punched at minimum times comparing with that of needle punched density 100 p m^{-2} and 150 p m^{-2}, which indicates that a low needle punched density and a high mass ratio of Al will contribute to magnetic shielding performance.



(a)

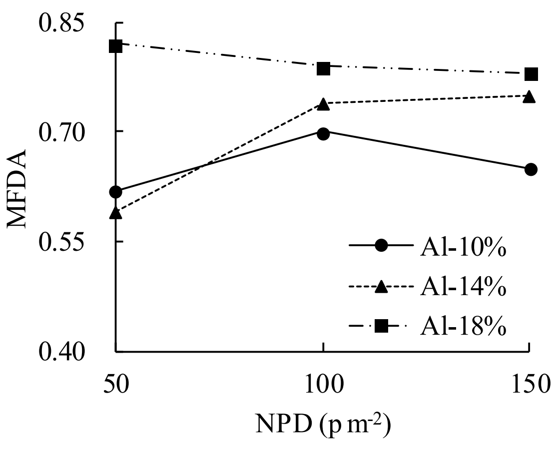


(b)

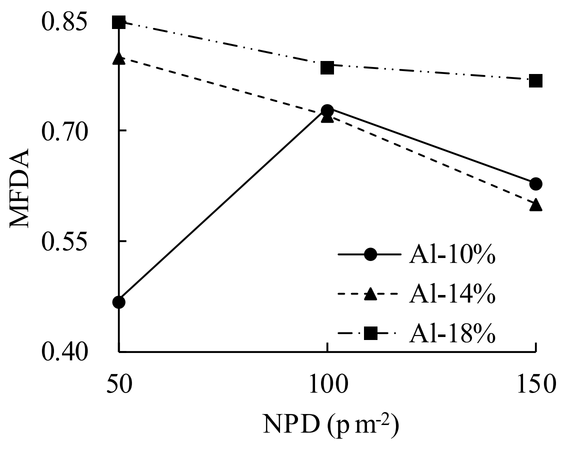
Figure 3. Relations between magnetic flux density attenuation value and mass proportion of Al. (a) needle punched depth 4mm, and (b) needle punched depth 5mm.

3.2. Influence of needle punched density on magnetic shielding performance

As shown in Figure 4 (a) and (b), taking needle punched density as abscissa axis and magnetic flux density attenuation MFDA values as ordinate axis, magnetic shielding performance curve was drawn and the influence of needle punched density on MFDA values was analyzed.



(a)



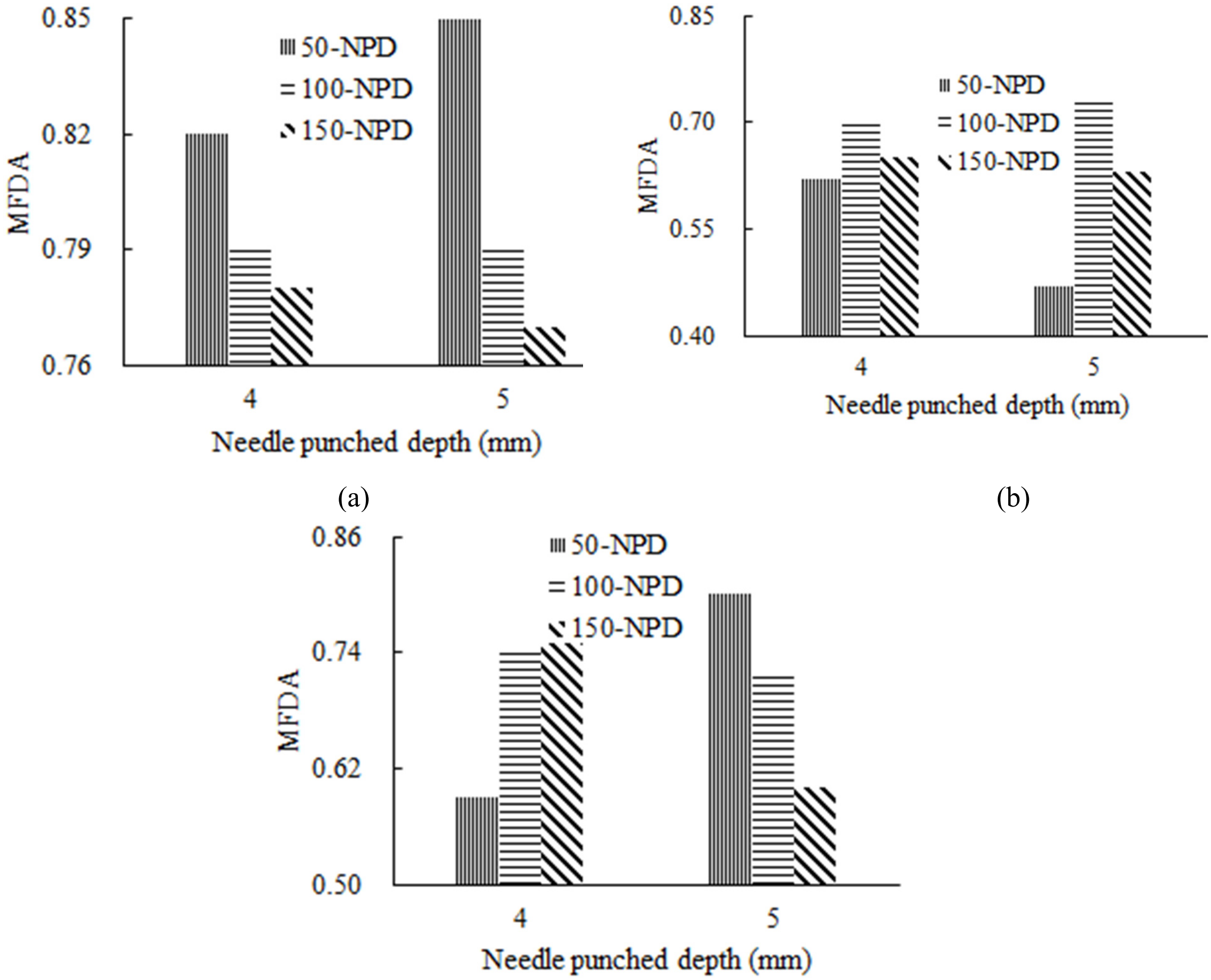
(b)

Figure 4. Relations between magnetic flux density attenuation value and mass proportion of Al. (a) needle punched depth 4mm, and (b) needle punched depth 5mm.

It can be seen that when needle punched density increases, MFDA values decrease or first increase and then decrease accordingly, keeping Al mass ratio unchanged. Owing to the higher needle punched density, Al film in needle punched web is more likely to be damaged, which will lead to reduction of magnetic shielding performance. However, if being confined to the limited way that the needle punched density of the Al / PET / Rayon needle punched web increases in, the product will be bonded tightly instead of being damaged, while Al is punched into a smaller interval and got tangled. Therefore, increasing needle punched density of a certain limit is helpful to raise magnetic shielding performance.

3.3. Influence of needle punched depth on magnetic shielding performance

As shown in Figure 5 (a), (b) and (c), taking needle punched depth as abscissa axis and magnetic flux density attenuation MFDA values as ordinate axis, magnetic shielding performance curve was drawn and the influence of needle punched depth on MFDA was analysed.



(a) (b)

(c)

Figure 5. Relations between magnetic flux density attenuation value and needle punched depth. (a) Al 10%, (b) Al 14%, and (c) Al 18%.

It is indicated that when needle punched depth rises from 4mm to 5mm, the MFDA values of the Al / PET / Rayon needle punched web processed are almost the same value, keeping needle punched density and Al mass ratio unchanged. Because the adjustable range of needle punched depth is narrow, the needle punched depth nearly has little effect on the status of Al film in needle punched web, therefore shows no significant effect on magnetic shielding performance. But there are exceptions when the needle punched density is 50 p m^{-2}. It can be seen that Al / PET / Rayon needle punched 50 p m^{-2} webs differ greatly with different needle punched depth. When Al mass ratio is 10%, MFDA value declines sharply with needle punched depth, while MFDA value has a marked increase in the case of Al mass ratio 14% and 18%, keeping needle punched density 50 p m^{-2}, which is even much better than the values in needle punched density 100 p m^{-2} and 150 p m^{-2}. It indicates that when needle punched density is reduced to a certain extent, such as 50 p m^{-2}, the effect of needle punched depth on MFDA value becomes obvious. The reason is thought to be that when needle punched density is 50 p m^{-2}, the Al film is punched at minimum times comparing with that of needle punched density

100 p m^{-2} and150 p m^{-2}, which offers a low needle punched density, and a low damage in Al film. Therefore, Al / PET / Rayon webs processed under the condition of needle punched density 50 p m^{-2} seems to show significant changes with needle punched depth. When Al mass ratio is low, a high needle punched depth will contribute to that destruction, so MFDA value decreases sharply. When Al mass ratio is high, a high needle punched depth will contribute to the tangling of Al and fibre webs. Hence MFDA value increases sharply, instead.

4. Conclusion

In this paper, experimental study of magnetic shielding performance on Al / PET / Rayon needle punched web under the exposure to mobile phone field was investigated. The paper evaluated the effect of three different positions of Al film in Al / PET / Rayon needle punched web on their magnetic flux density, and then processed Al / PET / Rayon needle punched webs by nonwoven technology, with verified parameters, which were Al proportion, needle punched density, and needle punched depth. Magnetic flux density values of Al / PET / Rayon needle punched webs were measured to calculate their magnetic flux density attenuation values. The relationships among their magnetic shielding performance and three variable parameters were analysed.

It was found that when mass proportion of Al in Al / PET / Rayon needle punched web increases from 10% to 18%, MFDA values increase accordingly, and tend to converge around Al mass ratio 18%. Besides, the promotion range of MFDA values is particularly obvious in the case of needle punched density 50 p m^{-2}.

When needle punched density increases from 50 p m^{-2} to 150 p m^{-2}, MFDA values decrease or first increase and then decrease.

When needle punched depth rises from 4 mm to 5 mm, the MFDA values of Al / PET / Rayon needle punched web are almost the same value. It is also indicated that when needle punched density is reduced to a certain extent, such as 50 p m^{-2}, the effect of needle punched depth on MFDA value becomes obvious. When Al mass ratio is low, a high needle punched depth will contribute to that destruction, so MFDA value decreases sharply. When Al mass ratio is high, a high needle punched depth will contribute to the tangling of Al and fibre webs. Hence MFDA value increases sharply, instead.

As a result, position of Al film, mass ratio of Al, and needle punched density show a great effect on magnetic flux density attenuation.

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References

[1] Sonehara M, Noguchi S, Kurashina T, Sato T, Yamasawa K and Miura Y 2009 *IEEE T. Magn.* **45** 4173
[2] Ozen M S, Sancak E, Usta A B I and Akalin M 2013 Text. Res. J. **83** 849
[3] Ozen M S, Sancak E and Soin N 2018 Fibers Polym. **19** 321
[4] Li T, Wang R, Lou C, Li J and Lin J 2014 Fibers Polym. **15** 315
[5] Ray S C and Ghosh P 2017 Indian J. Fibre Text. **42** 160
[6] Cardis E, Deltour I, Mann S, Moissonnier M, Taki M, Varsier N, Wake K and Wiart J 2008 Phys. Med. Biol. **53** 2771
[7] Gandhi O P, Morgan L L, Salles A A, Han Y Y, Herberman R B and Davis D L 2012 Electromagn. Biol. Med. **31** 34
[8] Tang J, Zhang Y, Yang L, Chen Q, Tan L, Zuo S, Feng H, Chen Z and Zhu G 2015 Brain Res. **1601** 92
[9] Yakymenko I, Tsybulin O, Sidorik E, Henshel D, Kyrylenko O and Kyrylenko S 2016

Electromagn. Biol. Med. **19** 1
[10] Hardell L, Carlberg M, Koppel T and Hedendahl L 2017 Mol. Clin. Oncol. **6** 462
[11] Chung D D L 2012 Carbon **50** 3342
[12] Yang Y, Gupta M C, Dudley K L, Lawrence R W 2005 Nano Lett. **11** 2131
[13] Su C I and Chern J T 2004 Text. Res. J. **74** 51
[14] Çeven E K, Karaküçük A, Dirik A E and Yalçin U 2017 Ind. Textila **68** 289
[15] Jung J, Lee H, Ha I, Cho H, Kim K K, Kwon J, Won P, Hong S and Ko S H 2017 ACS Appl. Mater. Interfaces **51** 44609
[16] Erdem O, Akay C, Cevher S C, Canseven A G, Aydın A and Seyhan N 2018 Biol. Trace Elem. Res. **36** 265
[17] Chauhan P, Verma H N, Sisodia R and Kesari K K 2016 Electromagn. Biol. Med. **36** 20