Acta Technica 62 No. 2B/2017, 703–712

Dielectric properties of single layer pyrrole coated fabric based on polypyrrole absorbing mechanism

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Abstract. Single layer pyrrole coated fabrics based on the absorbing mechanism of polypyrrole play an active role in the absorption of electromagnetic radiation of electronic products. In this study, the doping ratio model of dopant that has great influence on the dielectric properties of polypyrrole absorbing materials was studied. The morphology and dielectric properties of microwave absorbing materials with different mixing modes were compared. The results show that when the ratio of dopant/monomer is 0.1, the absorbing efficiency is the best, and the suitable dopant in the absorbing material is CBDS. The purpose of this study is to provide theoretical basis and technical support for further research.

Key words. Polypyrrole, absorbing wave, single layer pyrrole coated fabric, dielectric properties.

1. Introduction

With the development of the times, the current world has begun to enter the "electronic products" era. The development of computers, mobile phones and other household appliances has brought great fun and convenience to people's life, and has gradually brought positive impetus to the development of the world. The development of the electronic equipment has gradually become an important trend in the development of the times. However, some discordant phenomena are further revealed. With the increasing number of electronic equipment, the electromagnetic radiation caused by electronic products is gradually becoming more and more serious. Many studies suggest that some electronic radiation generated by electronic products not only brings certain restriction and negative influence to the operation and progress of other subsidiary electronic equipment, but also does harm to people's health. In this study, we mainly study the dielectric properties of single layer pyrrole coated fabric based on the mechanism of polypyrrole absorbing wave, ana-

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lyze and discuss the advantages of the whole electronic industry and industry. The purpose of the research is to provide a theoretical basis and scientific support for the development of new type of absorbing materials.

2. State of the art

Under the theme of new era development, electronic information technology has gradually become an important innovation technology in the new era. The development of these technologies has brought a lot of modern electronic equipment for many enterprises and industries, and it has also provided a positive impetus for the development of related industries [1]. However, the rapid development of the electronic equipment has also brought a series of problems such as electromagnetic pollution. Many researchers in different fields have studied the electromagnetic radiation and pollution. They think that if people are in the environment of electromagnetic radiation for a long time, they may have a series of diseases and variations such as tumor. Moreover, the development of some advanced electromagnetic weapons also poses certain threats to the security and environment, ecology and ecological balance in some areas [2]. Therefore, how to better solve this series of electromagnetic pollution problems has gradually become an important research topic of all countries in the world. In order to better to solve these problems, many researchers begin looking for related materials with a better absorbing performance, and analyze related properties of these materials, so as to obtain the relevant materials that can deal with electromagnetic pollution. Single layer pyrrole coated fabrics based on polypyrrole wave absorption mechanism have better dielectric properties [3]. Therefore, the study of this material has gradually become the main subject of study. The main effect of this kind of wave absorbing material is that it has certain electromagnetic absorption and treatment efficiency. It has gradually be applied in medical, military and other related industries, which has brought a positive and effective role in promoting the development of these industries. At the same time, absorbing materials with stronger wave absorbing efficiency and cost performance have also been gradually developed and applied to the actual production and life [4].

2.1. Methodology

The study on the current single pyrrole coated fabrics based on the mechanism of polypyrrole absorption was analyzed. Different morphologies of wave absorbing agents were prepared by using different preparation methods. Polypyrrole was prepared by using different materials in the study. The effect of these factors on the wave absorbing efficiency of the absorbing materials was determined by different proportioning methods and different production schemes [5]. The optimization of the related manufacturing process is to provide a theoretical basis and scientific support for the further study of related materials, and to provide a certain guarantee for the ecological balance and people's health in China. The main materials and methods of this study are as follows:

The experimental reagents used in this study were mainly used for the preparation of wave absorbing agents doped with polypyrrole. The main reagents are shown in Table 1.

Table 1. Main reagents used in this experiment

Reagent name	Purity	Production company
Pyrrole (Py)	CP	Sinopharm Chemical Reagent Co., Ltd.
Ferric chloride chloride ($FeCl_36H_2O$)	AP	Wuhan Huashun Biotechnology Co., Ltd.
Twelve sodium alkylbenzene sulfonate (SDBS)	AP	Beijing Aoboxing Biotechnology Co., Ltd.
Two (2-hexyl) sodium sulfosuccinate (AOT-Na)	AP	Tianjin Kermel Chemical Reagent Co., Ltd.
Sodium p-toluene sulfonate (pTSNa)	AP	Sinopharm Chemical Reagent Co., Ltd.
Camphor sulfonic acid (CSA)	AP	Sinopharm Chemical Reagent Co., Ltd.
Absolute ethanol (C_3H_3OH)	AP	Dongli Tianjin Tyrande Chemical Reagent Factory

First of all, a certain volume of deionized water was prepared before the preparation of polypyrrole absorbing material. The amount of 0.01 mol substance was doped into the sterilized deionized water of 100 ml, and a magnetic stirrer was used to mix the solution until a relatively stable milky liquid was formed. A pyrrole drug with the amount of 0.05 mol was added to a relatively stable emulsion. It was mixed using magnetic mixer, added into the three-flask, and placed at 0 °C to control the temperature of the solution. After the preparation of the mixed solution was complete, the deionized water solution mixed with ferric chloride was slowly dripped into the prepared mixed liquid with a gel dropper, and placed in a quiet state for about 6 hours. When the reaction state was stable, a certain amount of acetone was added to react. The final state was washed by deionized water until all the reaction systems exhibited a colorless and transparent state. The final reaction system was placed in a vacuum drying chamber of 60 °C for drying treatment. The dried product was grinded until it reached the powder state, so as to obtain the final polypyrrole (Cho, et al. 2014) [6]. In this study, polypyrrole without addition of any dopant was used as a control group. Samples of polypyrrole with different modes and ratios were obtained by adding different dopants. The related samples are shown in Table 2.

In this study, the infrared spectra of the samples related to polypyrrole based on different dopants were firstly determined by infrared spectrophotometer. In the determination of samples, the sample preparation was mainly dependent on the tabletting method. The wavelength range of the infrared spectrophotometer used can reach about 4000–400 cm^{-1}, so that it has a more reliable measurement accuracy [7].

Table 2. Labeling of polypyrrole samples doped with different dopants

Sample number	PPy-1	PPy-2	PPy-3	PPy-4	PPy-5	PPy-6	PPy-7	PPy-8
Dopant	$FeCl_3$	AOT-Na	SDBS	CSA	pTSNa	SDBS	SDBS	SDBS
Dopant/ monomer	0.1	0.1	0.1	0.1	0.1	0.2	0.4	1.0

The product of certain weight polypyrrole products was measured by elemental analyzer and X-ray technique, so as to ensure that there was no experimental deviation in the obtained polypyrrole product due to nonstandard experimental operation. In addition, it can provide certain protection and support for the accuracy improvement of follow-up related characteristics (Andrade, et al. 2014) [8].

On the basis of analyzing the external characteristics of polypyrrole products by using related software, the absorbing property of the polypyrrole was calculated and analyzed (Luo et al. 2013) [9]. In this study, the reflection coefficients of the wave absorbing agents at different ratios and times were calculated. The formula is

$$\Gamma = \frac{Z - Z_0}{Z + Z_0},\ Z = \sqrt{\frac{\mu_r}{\varepsilon_r}},\ Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}\,, \tag{1}$$

where, Z_0 stands for the characteristic impedance properties of different absorbing materials in relatively free space, Z represents the normalized value of characteristic impedance properties of some absorbing materials. The dielectric constant and permeability of the wave absorbing materials with different mixing ratio and different configuration time were calculated [10]. The main formulas are

$$\varepsilon_r = \varepsilon_r' - \mathrm{j}\varepsilon_r''\,, \tag{2}$$

$$\mu_r = \mu_r' - \mathrm{j}\mu_r''\,, \tag{3}$$

where, ε_r and μ_r represent the dielectric constant and magnetic permeability of various absorbing materials, respectively, ε_r' and $varepsilon_r''$ represent the variable values and loss measurements of some absorbing materials, respectively, μ_r' and μ_r'' represent the magnetization variables and loss measurements of some absorbing materials, respectively. On the basis of the calculation of the correlation characteristics, the tangent of the dielectric loss angle δ of various absorbing materials with different mixing ratio and different configuration time was calculated.

The relevant formulas are as follows:

$$\tan\delta = \tan\delta_\varepsilon + \tan\delta_\mu = \varepsilon''/\varepsilon' + \mu''/\mu'\,, \tag{4}$$

where, δ_ε and δ_μ show hysteresis in each absorbing material compared with the applied electric field and magnetic field. Therefore, only when the tan value shows a relatively large value can the further confirmation of this kind of absorbing material be made. Compared with other absorbing materials, it has stronger absorbing properties [11].

Finally, the absorption properties of different dopants and different modes were compared and analyzed by means of the acquisition and calculation of related parameters, so as to provide theoretical basis and technical support for the study of absorbing materials with relatively high wave absorbing efficiency.

3. Result analysis and discussion

With China's reform and opening up, China's various industries and fields have made great progress and development. Electronic equipment industry, as one of the most important technologies in the development of the times, is very important to the development of our country's industry. With the increasing proportion of China's investment in this field and industry, China's electronic equipment industry has already been developed in the world. However, the development of electronic equipment has posed a certain threat to the environment, ecological balance and health of our country. At present, China has gradually become aware of the risk of electronic radiation caused by electronic equipment, and the main way to solve this threat is to use some wave absorbing materials. Today, China has achieved some achievements in the study of related absorbing materials, and has made great progress in the use of related materials in various industries. The research and development of microwave absorbing materials and the gradual increase of frequency make our country begin to increase the development of related technologies (Fig. 1). In the absorbing materials, the main factor affecting the wave absorbing strength of materials is the selection of wave absorbing agents. How to better improve the performance of the absorbing material not only studies the selection of wave absorbing agents, but also needs to study and design all aspects of the overall properties and state of the related absorbers in the entire material. Therefore, the research and future trends of absorbing properties of materials in our country are mainly aimed at the following aspects:

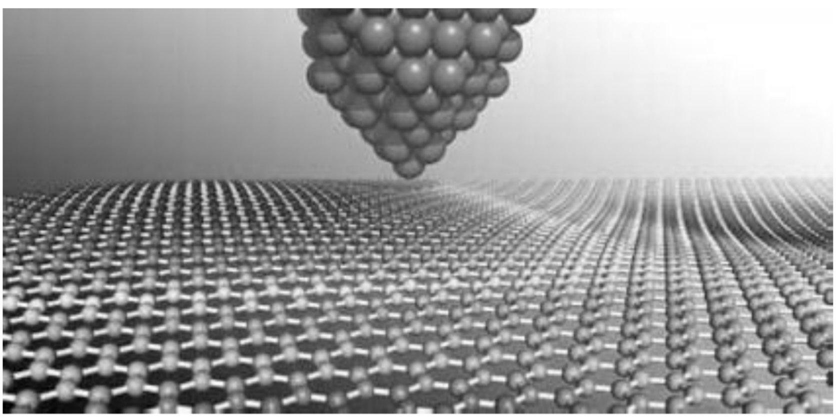

Fig. 1. Development of polypyrrole absorbing materials

For the main absorbers for absorbing materials already used in our country, we should further optimize the main characteristics of the relevant material and improve the related properties of the whole wave absorbing material through the relevant treatment methods to improve the absorbing material for absorbing electromagnetic radiation based on the analysis and comparison of its performance.

The characteristics of all used wave absorbers are analyzed. The microwave absorbing agents with strong wave absorbing property can be synthesized and used to make them perform their unique properties and advantages, and then form a new wave absorbing composite. The use of related materials is not only a single use of a material, but more complex forms of "1+1>2".

We should continue to develop some new wave absorbing materials and wave absorbers with stronger wave absorbing efficiency. Nano wave absorbing materials, which have been gradually developed and used in the current era, can be used as follow-up research contents. Many industries in our country have begun to introduce new ideas and apply them to the real estate industry. These new wave absorbing materials can obviously reduce the overall conductivity of the whole wave absorbing material, and further optimize the overall wave absorption structure, so as to better absorb the electromagnetic radiation. As a result, emerging materials, if used properly, may have stronger wave absorbing effectiveness.

On the basis of a thorough understanding of the development trend of polypyrrole absorbing materials, it is believed that the absorbing properties of materials and the morphology and size of absorbing material is related more closely by reading the relevant literature (Fig. 2). With the gradual development of processing technology, now in the design of related wave absorbing materials, usually the shape and size are specifically designed. The usual methods of manufacture include hard template method and soft template method. In the fabrication of the template method, it is usually classified according to the position of the absorber of polypyrrole. Some polypyrrole materials may grow on the inner side of the template. In this case, the method is often referred to as the inner template. Some may grow on the outer side of the entire template space, which is called the outer side. Two different template methods have their respective advantages and disadvantages. Therefore, after considering the size of the absorbing materials and their design materials and the future scope of the application, the two template methods are chosen to improve the microwave absorbing properties of the whole wave absorbing material. Because the hard template method has relatively tedious steps in the removal process of the template, it makes the whole production process of absorbing materials limited, which may affect the subsequent material absorbing efficiency. Under this trend, the soft template method has been gradually researched and produced. This method not only takes advantage of the hard template method, but also avoids the process of template removal, which makes the production process of the related wave absorbing materials show a more efficient trend. In this study, the polypyrrole absorbing material is designed by the soft template method.

On the basis of understanding and understanding of the related theories, this study designed and fabricated the absorbing products and materials of polypyrrole by different ratio methods. The main external morphologies and related character-

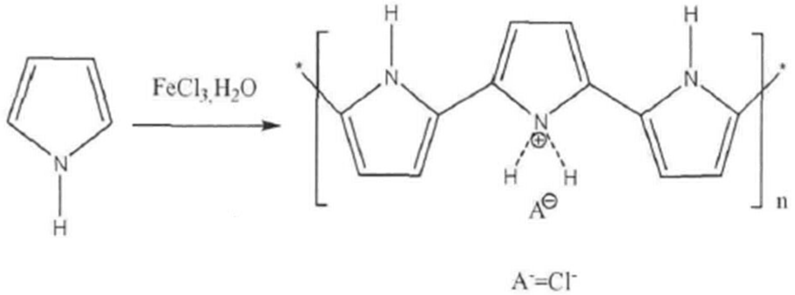

Fig. 2. Schematic diagram of the preparation of polypyrrole (soft template method, taking $FeCl_3$ as an example)

istics were analyzed by various techniques. The results are as follows.

Firstly, the ratio of dopant and monomer was studied. In this study, the wavelength of polypyrrole absorbing material under different ratios was analyzed by using infrared spectrophotometer and X-ray technique. The results are shown in Fig.3. Among them, a, b, c, d and e represented the ratio of the dopant and monomer for 0, 0.1, 0.2, 0.3 and 0.4, respectively. The results showed that when the ratio was 0.1, which was b spectrum, the spectrum peak value was higher compared to other energy state, which could be considered as the best ratio. This was also similar to the ratio scheme used in this study. The result of infrared spectrum analysis also showed that it was difficult to observe the vibration peak when the doping degree was relatively high. Therefore, the preparation of polypyrrole absorbing material was difficult to choose with relatively high doping degree.

The elemental composition of the polypyrrole absorbing materials with different doping levels was analyzed by elemental analyzer. The results are shown in Table 3. The results showed that the conductivity of the absorbing material was relatively high when the dopant ratio was low because a lower proportion of dopants had a positive effect on the flow of electrons. When the dopant ratio was high, it might hinder the electron flow and further reduce its absorbing capacity.

Table 3. Elemental analysis of polypyrrole with different doping levels

No.	SDBS/Py	Component				S/N	Conductivity (S/m)
		C	H	O	N		
PPy-3	0.1	57.86	5.37	13.09	2.76	0.21	9.07
PPy-6	0.2	60.09	5.99	11.36	3.49	0.31	4.98
PPy-7	0.4	61.07	5.34	10.54	4.49	0.43	3.91
PPy-8	1.0	66.49	7.11	9.19	5.64	0.61	0.93

The conductivity of polypyrrole absorbing materials with different dopant modes was calculated. The results are shown in Table 4. The results showed that the conductivity decreased and the wave absorbing efficiency decreased with the increase

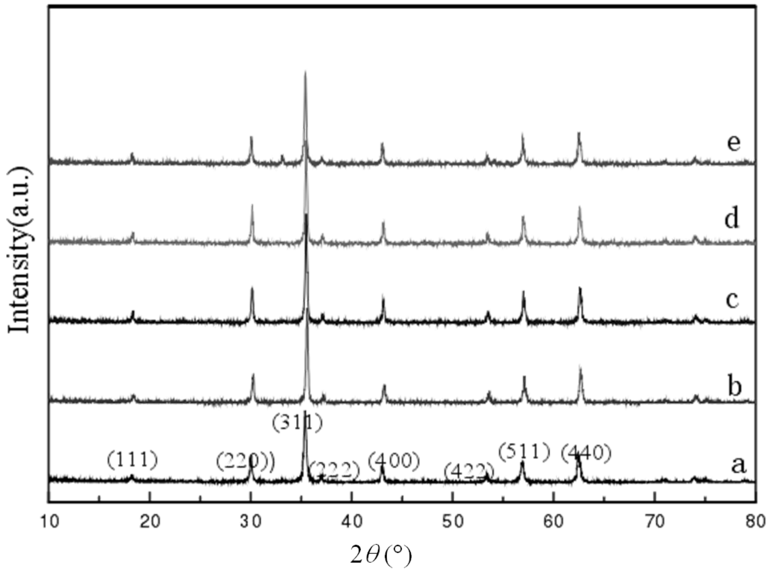

Fig. 3. X-ray diffraction patterns of polypyrrole absorbing materials with different doping ratios

of dopant ratio. However, the conductivity of the polypyrrole absorbing materials made by different dopants was also different. When SDBS was used as dopant, the conductivity of the absorbing material was the highest and the wave absorbing efficiency was the strongest.

Table 4. Conductivity of polypyrrole samples doped with different dopants

No.	PPy-1	PPy-2	PPy-3	PPy-4	PPy-5	PPy-6	PPy-7	PPy-8
Conductivity	2.70	9.44	9.07	3.21	4.98	4.98	3.91	0.93

4. Conclusion

With the development of the times, now the emergence of computers and other electronic products have brought great convenience for people's production and life, which has played a certain driving significance for people's industry and economic development. However, in the trend of the rapid development of electronic products, some uncoordinated phenomena are further exposed. For example, when working or using electronic products, they may cause a series of hazards such as electromagnetic radiation, which have a negative impact on human health and ecological balance. For this problem, a better solution is to do the preparation of some absorbing materials. The absorbing materials based on the principle of polypyrrole absorbing wave have begun to attract more and more attention, and have achieved a certain degree of progress and development. Under this trend, our country has begun to increase the study of wave absorbing materials. In this study, the mixing modes of dopant factors which have the greatest influence on dielectric properties of absorbing materials were compared and analyzed. The morphology and dielectric properties of microwave absorbing materials with different mixing modes were compared. The appropriate ratio and dopant were determined. The purpose of the study is to provide theoretical basis and technical support for follow-up studies. In this study, only the important factors have been analyzed, and there are some defects. However, it can provide technical support for the development of subsequent absorbing materials.

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Received October 10, 2017