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The Effect of Carbon on Chitosan-ZnO Composites as Fabric Mask Coating Materials

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ABSTRACT

Increasing the effectiveness of cloth masks can reduce the use of disposable medical masks which creates a new waste problem. In this research, the synthesis of zinc oxide nanoparticles was carried out using the precipitation method through the reaction between zinc nitrate and phosphoric acid as one of the ingredients in the chitosan-ZnO/C composite mixture. The carbon source is obtained from activated coconut shell carbon using sodium hydroxide. X-ray diffractometer (XRD) testing was carried out to determine the phase content of the synthesized carbon powder. XRD testing was also carried out on synthesized ZnO particles to determine the occurrence of phase transformations and to determine the quantitative and qualitative characteristics of the material. Fourier Transform Infrared testing was also carried out to observe functional group bonds formed in carbon compounds. Composite materials that have been successfully made will then be tested for hydrophobicity by calculating the contact angle. The results of this study indicate that the synthetic base material has been successfully carried out and the composite has been successfully made. The highest water contact angle is106^o was found in the chitosan/ZnO composite sample with a ratio of 2:1 and a mass variation of 0.05 gr active carbon.

Keywords: Zinc Oxide, chitosan, activated carbon, Composites, Masks

INTRODUCTION

Indonesia has entered the New Normal period since 2022. The use of masks in several areas is still being implemented, especially in several areas that are not categorized as safe and in dense urban areas. The high use of medical masks during the pandemic has created a new waste problem due to its disposable nature. Cloth masks can be an alternative because they can be reused so they can reduce the increase in medical waste. Cloth masks as health masks mostly use cotton. Cotton fabrics have many advantages, namely comfortable to use, soft, have an affinity for the skin, good regeneration and biodegradation. However, cotton cloth also has significant drawbacks, namely having hydrophilic properties, large surface area, and the ability to retain moisture so that it becomes a good medium for microorganisms to multiply. (Elangga, 2021). To overcome these deficiencies, additional material engineering is needed as a coating on cloth masks to increase filtering effectiveness and improve its function by adding hydrophobic properties so that no droplets stick.

The modification of cotton fabric that will be carried out is by using a polymer-ZnO/C composite. The use of ZnO in the composite composition to be made is based on its unique nature, environmental friendliness, biocompatibility, and economical price, and has been recognized as a safe substance by the US Food and Drug Administration (FDA). ZnO particles are one of the UV protectors because they have extraordinary and most effective photocatalytic activity, antimicrobial agents, thermal stability, non-toxic (Rofi & Maharani, 2020), increased hydrophobicity, and moisture control (Mandar & Zainul, 2019). The polymer to be used is chitosan. Chitosan is non-toxic and easily biodegradable. Chitosan is insoluble in water, in strong alkaline solutions, in H_2SO_4, and in some organic solvents such as alcohol and acetone. Chitosan is soluble in HCl and HNO_3 and dissolves well in weak acids, such as formic acid and acetic acid. Organic biopolymers such as chitosan have been extensively discussed in composite studies and their applications. Chitosan is a deacetylated derivative of chitin and the second largest type of polysaccharide in nature after cellulose (Lailiyah, Fadhila, Ramadhani, & Maharani, 2022).

Chitosan is easily decomposed, biocompatible, and non-toxic although there is still the possibility of causing allergies, can form thin films, and can adsorb. In addition, chitosan shows the presence of an amine functional group which has the ability as an antibacterial with low production costs (Farouk, 2012). The type of carbon to be used is activated carbon derived from coconut shells. Activated carbon is a porous solid made from carbon-containing raw materials with a special process so that it has an active surface and is selective in its use. Activated carbon is an amorphous carbon with a surface area of about 300 to 2000 m^2/gr. This very large surface area is due to its porous structure which causes activated carbon to have the ability to absorb (Laos, Masturi, & Yulianti, 2016). Activated carbon has long been used in water purification and wastewater treatment processes and the treatment of hazardous industrial exhaust gases. (Wuntu & You, 2008).

In this research, the effect of carbon on polymer-ZnO composites as a cloth mask coating material will be studied. The method that will be used to form ZnO particles is the coprecipitation method. The coprecipitation method was chosen because it is easy to do and can be done at low temperatures (Harsono, 2022). Next, a polymer-ZnO/C composite will be made as a coating for cloth masks. The resulting composite material is expected to increase the effectiveness of cloth masks as health masks that are more environmentally friendly because they can be used repeatedly.

MATERIALS AND METHODS

The research method used systematically can be seen in the following chart,

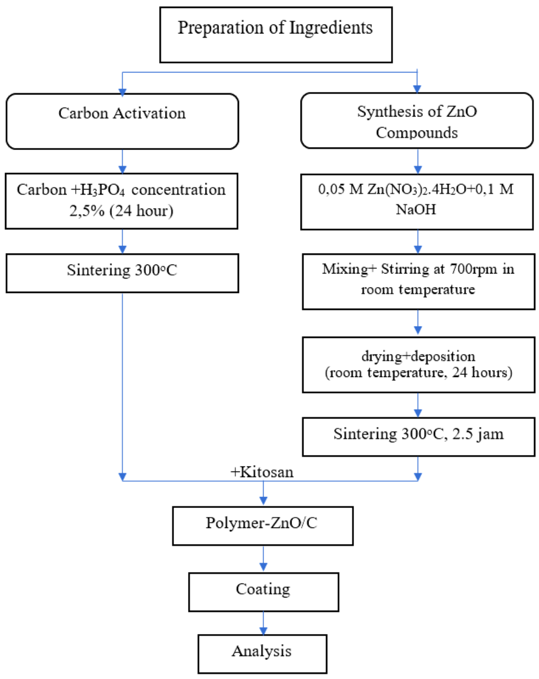

Figure 1. Flowchart for the Production of Polymer-ZnO/C Composites

Carbonization and Activation of Carbon Making activated carbon begins with the carbonization process on coconut shells to obtain charcoal. Charcoal can be activated with a solution of phosphoric acid (H_3PO_4). The chemical activation process was carried out by immersing coconut shell charcoal in a 2.5% concentrated H_3PO_4 solution for 24 hours and sintering at 300^{o}C (Laos, Masturi, & Yulianti, 2016).

Synthesis of ZnO Compounds

The reagent used in the synthesis of zinc oxide nanoparticles is an analytical reagent grade without re-purification. The synthesis of colloidal nanoparticle solutions was carried out by precipitation. Zinc oxide is prepared by reacting 0.05 M $Zn(NO_3)_2.6H_2O$ and 0.1 M NaOH and adding 0.5% surfactant. The NaOH solution was added drop by drop to the $Zn(NO_3)_2$ solution which had previously been given a surfactant. The solution was stirred on a magnetic stirrer at 700 rpm at room temperature. The speed of adding NaOH solution to the Zn precursor solution is 2 mL/minute. The stirring process was continued for 2 hours after the NaOH solution was used up. The solution was decanted overnight. The precipitate was washed with distilled water and decanted repeatedly. The zinc oxide precipitate was filtered off using a vacuum pump and dried in an oven at 80^{o}C overnight before heating for 2.5 hours in a furnace at 300^{o}C.

Preparation of Chitosan-ZnO/C Composite.

The preparation of the ZnO/C chitosan composite was started by preparing a 1% chitosan solution, 1 gr of chitosan was added to 100 ml of 2% acetic acid (Fadhila & Maharani, 2022). Chitosan sol was added with ZnO powder in a ratio of 2:1 and stirred at 900 rpm at 80^{o}C for 2 hours. Furthermore, the volume of chitosan/ZnO sol was made constant, namely 10 ml, while the mass of activated carbon was varied at 0.01 gr, 0.03 gr, 0.05 gr, and 0.07 gr, then stirred to form a chitosan-ZnO/C composite material which was then tested and analyzed.

RESULTS AND DISCUSSION

The results of making activated carbon powder from coconut shells have been carried out using a systematic research method. The elemental carbon content obtained contains as much as 72.6% carbon and there is an impurity of 27.4% carbon dioxide. The calculation of the level of water content that is owned by the carbon sample is at 6.70%. The less water content contained in activated carbon that it can produce larger the pores. The larger the pores, the surface area of activated carbon increases. thereby increasing the adsorption capacity of activated carbon. By increasing the adsorption capacity of activated carbon, the better the quality of the activated carbon. Based on the results obtained, the quality of the activated carbon produced in this study was quite good (Laos, Masturi, & Yulianti, 2016). the water content contained is by the requirements according to SNI 06-3703-1995, namely a maximum of 15%. Furthermore, the Fourier Transform Infrared (FTIR) test is used to characterize the structure and to determine the functional group bonds formed in the sample.

FTIR is a spectroscopy tool that uses the Fourier transform method to measure the absorption of the infrared spectrum emitted from the source to the test material at various wave numbers (Darminto, Baqiya, & Asih, 2018). The results of the FTIR test will show a graph of the pattern of peaks from the interaction of each molecule in the test material that absorbs energy from the infrared spectrum as shown in the graph of the relationship between transmission percentage (%T) and wave number (cm-1) as shown in Figure 2. below,

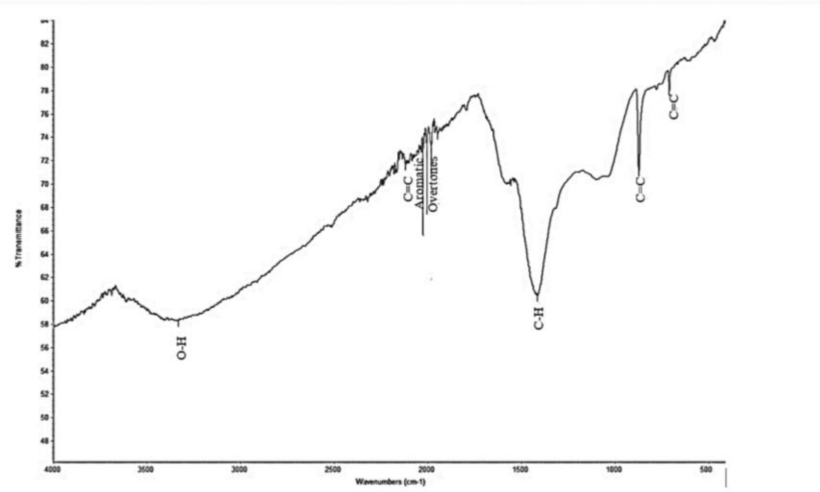

Figure 2. Carbon powder FTIR results

Based on the FTIR graph of coconut shell powder, shows the presence of other functional group bonds such as O-H, CH, and aromatic overtones besides the C=C double bond. C=C strain vibration was detected in two wave number ranges namely 712-873 cm^{-1} and 2120 cm^{-1} which belong to the group of aromatic compounds and alkene and alkyne functional groups. Another bond observed is C-H in the range of 1416 cm^{-1} which is an alkane group. Hydroxyl functional groups (O-H) were also detected with wide and deep transmission peaks. This indicates that there is a large enough absorption energy from the infrared spectrum for the sample. The O-H groups will experience deoxygenation during heating so that the strain vibrations will become weaker.

The ZnO precursor samples obtained through the synthesis process were tested using an X-ray diffractometer (XRD). The XRD results showed that the samples given different treatments at sintering time showed the formation of a peak pattern of 100% ZnO compound with peaks of 2θ 31^o, 34^o, 36^o which corresponds to the diffraction pattern of zinc oxide (PDF 96-900-8878). The graphical results of the diffraction peak pattern are shown in Figure 3.

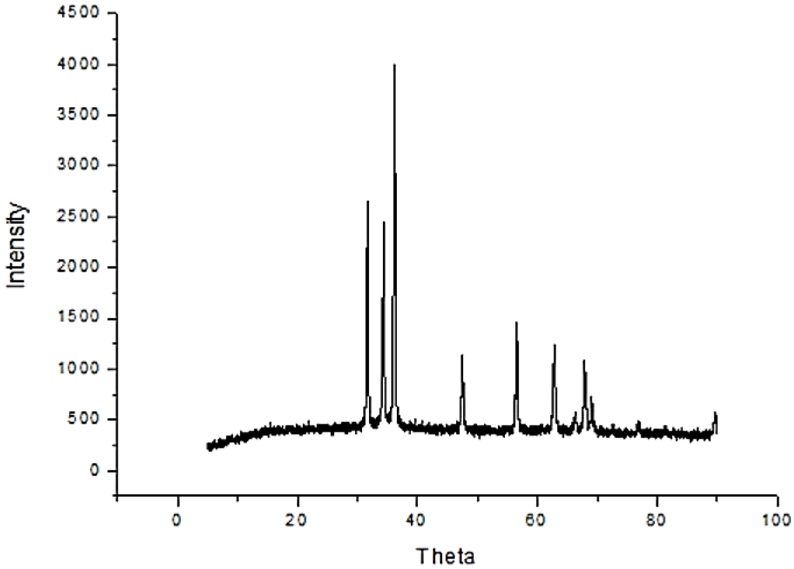

Figure 3. ZnO powder XRD results

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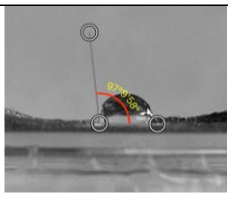
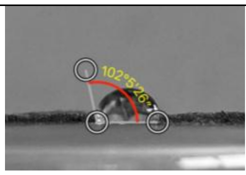
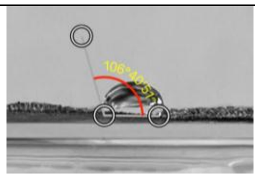
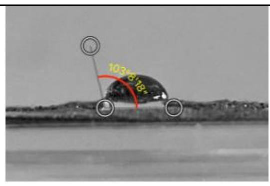
Cotton cloth has comfortable characteristics so that it can be applied as a protective face mask that functions as a filter for particles, viruses, and bacteria in the nose and mouth. Cloth masks have the advantage of being able to be washed and used repeatedly. However, cloth masks are easily dampened causing bacteria to multiply, therefore the mask must be kept from getting damp from droplets or from moisture when we breathe or other factors, so the mask must be hydrophobic (waterproof). To determine the waterproof properties of the fabric, a hydrophobic test is carried out.

Hydrophobicity test of fabric coated with chitosan-ZnO, chitosan-ZnO/TiO_2, and chitosan-ZnO/SiO_2 composites used the Water Contact Angel (WCA) method. Fabrics with hydrophobic properties can be produced in several ways, namely modifying the hydrophilic surface with a hydrophobic coating or coating the surface of the fabric with chemical compounds that have low surface energy so that the surface can retain water. Hydrophobic Textiles have water-repellent properties with a water-contact angle of $90^0 < \theta^0$ the higher the contact angle, the greater the liquid-liquid interaction strength becomes, making the material more hydrophobic.

The fabric coating process is carried out using the dip-coating method. The cotton cloth that will be coated must first be cut to a certain size and prepared so that the cloth is clean from adhering dirt. The cotton cloth is dipped in an ethanol solution to remove impurities such as traces of dirt from cutting the cloth. This process can also sterilize the surface of the cloth from bacteria that can interfere with the coating process, then dip it in distilled water to clean the cloth from dirt so as not to interfere with the coating process on the surface of the cloth. The washed cotton cloth is heated at 100^0 C for 50 minutes so that the cloth dries and the ethanol and water evaporate to carry away the dirt that sticks to the surface of the cloth. The fabric that has been coated with the composite is then tested for its hydrophobicity level. The results of the test can be observed in Table 1.

Table 1. Contact angle data on Chitosan-ZnO/C composite fabrics

Sample	Results	Contact Angle Value
Sample A		97^0
Sample B		102^0
Sample C		106^0
Sample D		103^0

Based on the results of the chitosan/ZnO composite coating with activated carbon variations of 0.01, 0.03, 0.05, and 0.07 gr respectively, it has a contact angle of 97^0, 102^0, 106^0, 103^0 which is hydrophobic because the water contact angle (WCA) value is greater than 90^0. The water contact angle is influenced by the level of surface roughness, cohesion, and surface tension can also affect the water contact angle. Fabrics with a high water contact angle

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have a high surface roughness, due to the high hydrophobicity of the surface so that water droplets roll off immediately and easily pick up adhering dirt particles with it (Thi & Lee, 2017). Hydrophobicity can also be affected by the composite chemical compounds that coat cotton fabrics. In this study, a chitosan-ZnO composite was used because the combination of chitosan and inorganic compounds in the form of nanoparticles will increase the mechanical strength of weak textiles (Hidayah, Damajanti, & Puspawiningtiyas, 2015). Combining chitosan with inorganic metal oxide compounds, one of which is ZnO, will increase the abrasion resistance of chitosan on fabrics. The results of adding carbon to the composite mixture showed that the highest contact angle was obtained from sample C of 106^{o}. The results of adding various activated carbons with the dip-coating method still had weaknesses, namely the distribution of carbon in the fabric was uneven, so to prove whether adding carbon mass to the composite could increase its hydrophobicity still needs to be studied again. Even so, from the overall level of coating variation, satisfactory contact angle level results have been obtained.

CONCLUSION

The results of the research that has been done can be concluded that the coating of the chitosan-ZnO/C composite is proven to increase the hydrophobicity of cotton fabrics. Variations in the addition of carbon mass affect the level of hydrophobicity, but further research still needs to be done regarding more effective coating methods so that the distribution of carbon on the fabric surface can be more even. Physical weaknesses found in adding excess carbon mass to chitosan-ZnO sol are weak adhesion and uneven surface finish.

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