Conference Paper

Renewable Silica-Carbon Nanocomposite and Its Use for Reinforcing Synthetic Wood Made of Rice Straw Powders

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Abstract

The current study was aimed to prepare and to characterize a renewable silica-carbon nanocomposite from rice straw ashes. It was purposed also to study the use of the produced nanocomposite as reinforcing material in producing a synthetic wood made of three axial blend of treated rice straw powder, phenolfrmaldehyde resin, and the nanocomposite. A simple preparation route of nanocomposite silica-carbon from rice straw was formulated containing three steps, namely pretreating of rice straw, preparing of ultra fine amorphous black silica, and composing silica-carbon nanocomposite. The nanocomposite product was characterized using XRD, XRF, FTIR and SEM methods. The characterization results comfirmed that the silica-carbon nanocomposite was succesfully prepared. The utilizing of the nanocomposite as reinforce material in producing synthetic woods was conducted through hot-pressing some three axial blend compositions of the pretreated rice straw powder, phenolformaldehyde resin, and the nanocomposite. The synthetic wood products were characterized their physical and mechanical properties. As a result, the addition of the nanocomposite could improve the properties of the synthetic wood products.

Keywords: Rice straw, silica-carbon nanocomposite, synthetic wood

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1. Introduction

Some high siliconeous tropical plants were prepeviously investigated in order to find prospective raw material candidates for producing renewable silica based materials [1]. Both rice husk and rice straw are the best candidate as raw materials for producing renewable silica powder because of their high content of silicon, natural abundance as tropical agricultural waste as well as low cost production. Thus the renewable silica from high siliconeous tropical agricultural wastes especially from paddies wastes has some advantages comparing to silica from earth deposits. The renewable silica powder is mailny amorphous and more reactive than silica powder of crystalline quarts minerals. Instead of amorphous silica powder, the rice husk and straw wastes can produce active carbon powders having high surface area [2]. The ratio contents of silica and carbon of the burned high siliconeous biomasses depend on pre-teatments, burning temperatures and length of burning as reported previously by some researchers [3,4]. The ash fine powders with certain silica-carbon ratios are potentialy resembled into a renewable silica-carbon nanocomposite.

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Silica-carbon nanocomposites, nowdays, have been taken into attractive attention because of their superior properties, namely mechanical, thermal, and dispersion properties [5] and their ability as reinforcement materials [6]. Some synthesis methods of silica-carbon nanocomposites had already reported previously [5,7], but the methods used non renewable starting materials causing high cost of production. Considering the reactive properties of amorphous silica and carbon contents of the black ashes produced from the controlled burning of high siliconeous agricultural wastes, such as rice straw and rice husk, a renewable nanocomposite silica-carbon could be synthesized cheaply and environmental friendly. The term renewable silica-carbon nanocomposite here means that the composite is produced from renewable raw materials from plants or animals, in this case, the raw material is rice straw.

Nowadays, the reduce of tropical rain forests because of the massive uses of tropical woods becomes sensitive global issues. It leads to the campaigne of substituting natural woods by synthetic woods. Since it was firstly patented by Himmelhelber et al. [8] as particle board, the synthetic woods were improved their technologies by some further inventions, such as a borate treated consolidated wood particle board [9], compression moulding of cellulosic fibers with thermoplastic additives [10], multilayer particle board with varying densities [11], and reinforcement of particle board during manufacture by using glass fiber [12]. However, the synthetic wood production technologies mostly used the natural wood particles as raw material or as cellulosic fiber resources. Non-wood cellulosic fibers such as wheat straws [13,14] were rarely used as raw materials because of some structural and mechanical limitation instead of their environmental and production cost advantages. Nanocomposite silica-carbon made from high siliconeous tropical biomasses may overcome those limitation by reinforcing the wood synthetic during manufacture. This current study was aimed to prepare nanocomposite silica-carbon from rice straw ash and to use it for reinforcing synthetic wood from rice straw lignocellulosic powder and phenolformaldehyde resin as binder.

2. Experimental Part

The experiments consisted of three parts, namely the preparation of ultrafine amorphous silica-carbon powder (UFASCP) from rice straw and silica-carbon nanocomposite (SCNC) from the UFASCP, the characterization of UFASCP and SCNC, and the utilizing of SCNC as reinforce material in the production of synthetic wood.

Firstly, the preparation processes of UFASCP and SCNC were conducted as follows. The rice straws of IR-64 paddy variety were taken from rice field of Tabanan Regency of Bali Province. The straws were chopped, leached using HCl 1 M, cleaned using water and then dried. The dried chopped straws were burnt in a furnace at the controlled temperature of 400°C and less oxygen atmosphere for about four hours to produce black ash powder. The rice straw black ash powder (RSBAP) was measured its silicon content and its impurities using XRF spectroscopy. RSBAP was rinsed using HCl 1 M, 2 M, and 3 M respectively, and finally it was rinsed using distilled water, hence metal oxides containing in the RSBAP could be removed. The rinsed RSBAP was acidified using H_2SO_4 solution 1 M. Furthermore it was heated in hydrothermal condition at 100°C (1 atm, 24 hours) in a sealed autoclap. The resulted powder was wetted by adding some drops of distillated water. The wet powder was finally milled using ball-mill a long 24 hours. The fine milled black powder was neutralized using NaOH solution 1M and then rinsed using distillated water. The rinsed black powder was dried. The dried fine powder was further calcined at 110°C for 4 hours. The resulted dried fine powder was then called as UFASCP. The transformation of UFASCP into SCNC was conducted in several steps. UFASCP was mixed with organic solvent of etanol 10% v/v and NaOH solution 0.2 M. The mixture was blended and milled using ball-mill in room temperature for 24 hours. The milled mixture was autoclapped over night (at least 24 hours) at 100°C (1 atm.) hidrotermally. The autoclapped powder was rinsed using solutions of HCl 3 M, 2M, 1 M, and distillated water respectively until the residual water was neutral. After drying, the powder was calcined at 100°C for one hour. The final powder was called silica-carbon nanocomposite (SCNC) from rice straw.

Secondly, the resulted UFASCP and SCNC powders were characterized by using several instruments, namely XRF, XRD, SEM, and FTIR spectroscopy. XRF PANalytical Minipal 4 Sulfur was used for elemental analysis with parameters of measurement of 28.00 kV, 53 uA (air, 60 sec., 41695.4 cps, standardless). Philip X'Pert Powder Diffractometer was performed for XRD measurements at tension of 20 kV, current of 5 mA and using Cu-Kα anode, 2 theta of 5 – 85 degree for 0.02 step/sec.. SEM measurements were conducted by using JEOL-JSM-6510LV in high vacuum mode 3.0 nm (25 kV) with magnifician of 30.000x. FTIR-8000 PC Shimadzu was performed for infra red spectroscopy measurements of samples with wave length number of 400 – 4000 cm^{-1}.

Finally, the experiment of using the SCNC as reinforcing materials in the synthetic wood from rice straw was conducted in four steps, ie. preparation of lignocellulosic fiber powder from rice straw, preparation of phenolformaldehyde (PF) resin using procedure elsewhere [15], preparation of three axial blends containing lignocellulosic fiber powder, PF resin, and SCNC powder in five compositions, namely: 80: 20: 0; 75: 20: 5; 70: 20: 10; 65: 20: 15; and 60: 20: 20 respectively, and preparation of the wood products by hot pressing the blends using hidraulic hot press at pressure comparable to stress of 200 Kg/cm^2, and at temperature of 80°C. The resulted synthetic woods were characterized their water absorptions measured using the standard test method of ASTM D7433 and compressive strenghts using Universal Testing Machine with standard of measurement ASTM D143 to see the reinforcing effects of the silica-carbon nanocomposite towards those properties of the resulted synthetic woods.

3. Result and Discussion

XRF analysis results on the samples of SBAP, UFASCP, and SCNC were depicted on the Table 1. Along processes of making UFASCP from RSBAP there was removal of metal oxide impurities, thus the percentage of silicon content was increased significantly, although not all elements could be detected by XRF, for instances sodium, carbon, oxygen, and other elements. The comparison reported here was only the observed elements by XRF spectroscopy.

Sample	XRF Elemental Analysis in procentage												
RSBAP	Si	S	K	Ca	Cr	Mn	Fe	Ni	Cu	Zn	Mo	Yb	Re
	24.5	29.2	3.15	7.11	0.38	0.19 ± 0.01	3.11 ± 0.01	0.29 ± 0.02	0.20 ± 0.01	0.42 ± 0.01	31.00 ± 0.50	0.10 ± 0.05	0.30 ± 0.04
UFASCP	Si	K	Ca	Ti	Fe	Ni	Cu	Zn	Ba	Yb	Re		
	83.0 ± 0.6	0.94 ± 0.01	10.70 ± 0.10	0.20 ± 0.03	1.30 ± 0.03	0.20 ± 0.09	0.63 ± 0.02	0.10 ± 0.03	1.40 ± 0.01	0.60 ± 0.03	1.00 ± 0.01		
NCSC	Si	K	Ca	Cr	Mn	Fe	Ni	Cu	Zn	Yb	Re		
	89.9 ± 0.06	1.60 ± 0.03	4.47 ± 0.04	0.36	0.18	2.21 ± 0.02	0.22 ± 0.03	0.35 ± 0.01	0.07 ± 0.01	0.10 ± 0.02	0.60 ± 0.01		

TABLE 1: Results of XRF Analysis on SBAP, UFASCP, and NCSC Samples.

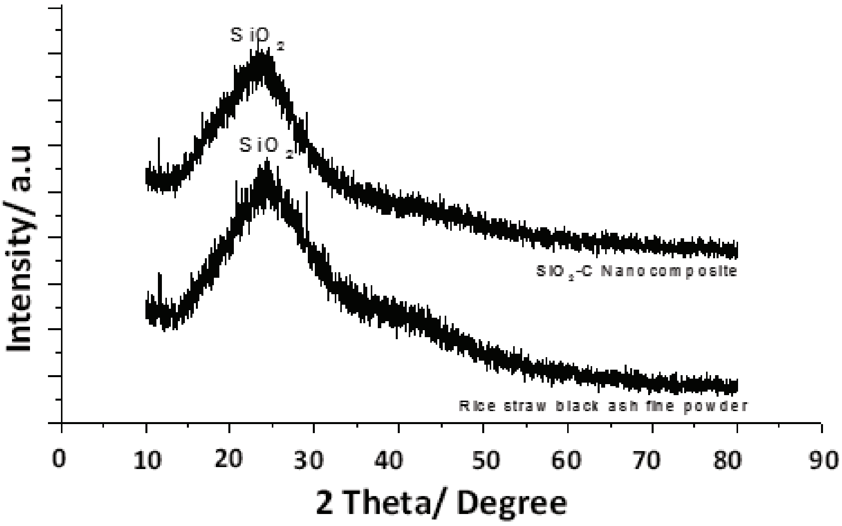

Figure 1: Diffractograms of UFASCP and SCNC.

Diffractograms resulted by XRD measurement of UFASCP and SCNC can be seen in Fig. 1. Both diffractograms have broadening peaks that indicate amorphous phase with small particle sizes. SCNC diffractogram has more boadening peak and the peak shifts to smaller 2 theta. The facts mean that SCNC is more amorphous and bigger grain size that those of UFASCP.

Comparing with the micrograph of UFASCP, the grains on micrograph of SCNC are more bigger size and more homogen than those of UFASCP as shown by Fig. 2. It can be confirmed by the results of EDX measurement showing the grains composed from only three elements Si, O, and C. The data shown on Fig. 1 and Fig. 2 may comfirm that a silica-carbon nanocomposite could be formed.

The characterization on synthetic wood produced by hot-pressing the three axial blends with variation of composition showed that the addition of SCNC can inprove the quality of the resulted synthetic woods, namely smaller water absorption and higher compressive strength values, as depicted on Fig. 3. The composition of the lignosellulosic agrifiber, PF resin, and SCNC of 70: 20: 10 can be chosen as the most

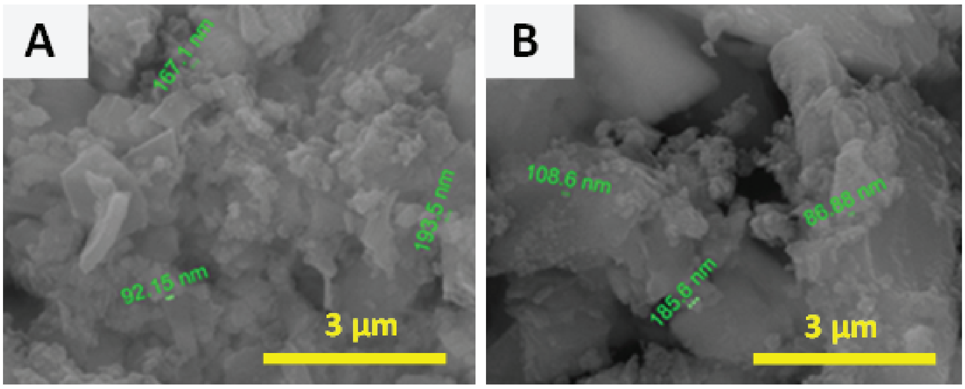

Figure 2: SEM Micrographs of UFASCP and SCNC.

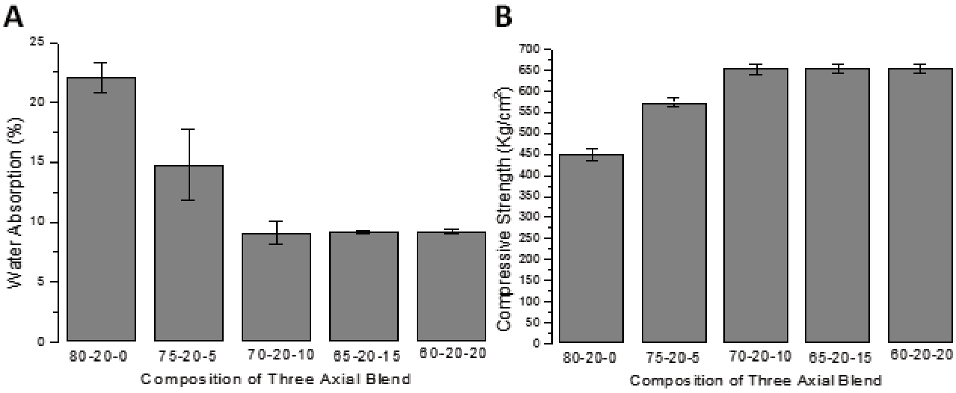

Figure 3: (A) Water Absorption and (B) Compressive Strength of Synthetic Woods.

effective composition of the three axial blend in producing synthetic wood using this procedure.

4. Conclusion

Silica-carbon nanocomposite was successfully prepared through transforming the ultrafine amorphous silica-carbon powder. The ultrafine powder was prepared from rice straw powder through pre-treating, controlled burning to produce black ash, and treating the ash. The use of the resulted nanocomposite can reinforce the properties of synthetic wood from rice straw lignocellulosic fiber.

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