EFFECT OF GAMMA ^{60}Co IRRADIATION ON MORPHOLOGY OF CARBON/SODIUM LAURYL SULPHATE (CARBON/SLS) USING A NOVEL SEM-EDS

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Abstract. Activated carbon is a material that has many benefits both in the health, energy such as storage materials and fuel cells, and industrial sector. Highly benefit of carbon material encourages researchers to activate it by various efficient methods. Activation carbon methods consist of two, by chemical and physical activation. Using chemical compounds, both acids, bases, and salts can increase carbon activity. Degradation of cellulose structure in natural materials by chemical compounds can increase its surface area. However, the presence of chemical compounds like acids and bases can pollute the environment. Another methods of activation carbon is electromagnetic waves used. In this research, electromagnetic wave irradiation will be carried out on carbon. The electromagnetic waves used gamma exposure from ^{60}Co gamma sources. Gamma electromagnetic exposure is clean energy without residual chemical compounds. This preliminary experiment aims to determine effect of ^{60}Co gamma irradiation on the morphology of carbon materials at dose of 40 kGy using scanning electron-energy dispersion spectroscopy microscopy (SEM-EDS). The results showed that effect of irradiation exposure ^{60}Co gamma on the morphology of carbon/SLS was unsmooth particles formation, which indicates that carbon/SLS can be used as adsorbent. Moreover, the presence of surfactant causes the carbon particles not to agglomerate or to be easily dispersed. ^{60}Co gamma irradiation also causes carbon become rich in oxygen which comes from free radicals.

Keywords: Gamma, carbon, surfactant, irradiation

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Introduction

Activated carbon is a functional material that has many advantages, such as energy storage applications in batteries, supercapacitors, and fuel cells [1]. Activated carbon with high electrical and optical thermal characteristics is used in biosensors and drug delivery systems in medicine [2-3]. Carbon nanomaterials are also used for water treatment in removing heavy metal ions, such as graphene or modified graphene [4].

Beside on previous experiments, carbon is a material from abundant renewable sources and affordable exploration costs [5-10]. Various nanocarbons show good photoluminescence stability, a large two-photon absorption area, and have good functionalization capabilities [11-14]. In addition, nanoporous carbon derived from metal-organic frameworks (MOF) has a very high surface area so that it can be applied for various purposes [15,16]. Moreover, nanoporous carbon has well-controlled porosity, thermal and chemical stability, catalytic activity, and high electrical conductivity [17]. Recently, MOF-based non-porous carbon was applied as a cation-exchange membrane and a compatible nanofiller to prepare pervaporation membrane matrices [18-21].

Carbon can be extracted from burning natural materials specially in agricultural waste, such as bagasse, pineapple fruit biomass, various ores, coconut shells, etc. A known natural method of making carbon from agricultural waste is wood burning, but this causes environmental pollution due to carbon dioxide emissions [1]. There are several scientific methods for converting biomass into carbon nanomaterials that can improve their structural and functional properties [22]. Biological methods are also often used as methods for the production of nanostructured carbon materials [23]. The process or conditions for nanocarbon synthesis can be adjusted to the structure of the product to be produced, including pore size, surface area, chemical composition, and functional groups [24-26]. For example, the reduction of graphene nanosheets to graphene oxide was carried out using the Hammer method to obtain high-purity, cost-effective, environmentally friendly, and efficient graphite [22].

Highly benefit of carbon material encourages researchers to activate it by various efficient methods. The first step of making activated carbon from natural materials consists of several methods, such as pyrolysis, hydrothermal, carbonization, and microwave [27-29]. The second stage is the activation by chemical and physical activation. The use of several chemical compounds, both acids, bases and salts can increase carbon activity. Degradation of cellulose structure in natural materials by chemical compounds can increase its surface area. However, the presence of chemical compounds like acids and bases can pollute the environment. The physical activation method to degrade the cellulose structure is carried out by heating at high temperatures. The consumed power is quite high, so that is less efficient for the activated carbon synthesis method. Another physical activation method is electromagnetic waves used. In this research, electromagnetic wave irradiation will be carried out on carbon. The electromagnetic waves used gamma exposure from Cobalt-60 sources. Gamma exposure electromagnetic is clean energy without residual chemical compounds.

This preliminary experiment aims to determine effect of ^{60}Co gamma irradiation on the morphology of carbon materials at dose of 40 kGy using scanning electron-energy dispersion spectroscopy microscopy (SEM-EDS). The carbon material is modified by sodium lauryl sulfate which acts as surfactant. The purpose of sodium lauryl sulfate surfactant on carbon materials is to increase the adsorption capacity of activated carbon [30-32].

Materials and Methods

Synthesis Activated Carbon/SLS

Commercial carbon is washed by distilled water three times, then dried in oven at 90 ºC for ± 3 hours. Furthermore, carbon is added Sodium Lauryl Sulfate (SLS) 60 ppm as surfactants, contacted or immersed for 4 hours [31]. The solution filtered to separate the filtrate and residue. The residue in the form of SMC (surfactant modified carbon) will be irradiated.

Irradiation of Synthesis Activated Carbon/SLS

Synthesized SMC (surfactant modified carbon) material was irradiated by dose gamma irradiation 40 kGy ^{60}Co at gamma irradiator facility, Polytechnic of Institute Nuclear Technology, National Research and Innovation Agency Yogyakarta, Indonesia.

Characterization Techniques

Detection of surface SMC (surfactant modified carbon) morphology is used scanning electron-energy dispersion spectroscopy microscopy (SEM-EDS) techniques Hitachi type SU3500. Material preparation used gold coating 10 mA and 20 s, ion sputter Hitachi MC1000. SEM Configuration Vacc 3 kV, SI 30%, apperture 3; adjustable magnification; low vacuum; secondary electron detector EDS by configuration Vacc 5 kV and SI 70%.

Results and Discussion

Gamma radiation is one of electromagnetic wave type that could degrade carbon structure into smaller size. Gamma radiation was used because of its efficient, fast, clean, user-friendly, and well-controlled techniques for improving the properties of polymeric materials for nuclear, construction, medical, and health-care in a variety of environments. Optimum dose of gamma radiation for grafted on polymer was 1-30 kGy with a dose rate of about 1-3 kGy/hours. Figure 1 is an illustration of the gamma irradiation process on the polymer chain [33]. Because of free radical production, carbon/SLS-irradiated ^{60}Co gamma is rich of oxygen element, about 46% weight, that has lowest percentage error (5%).

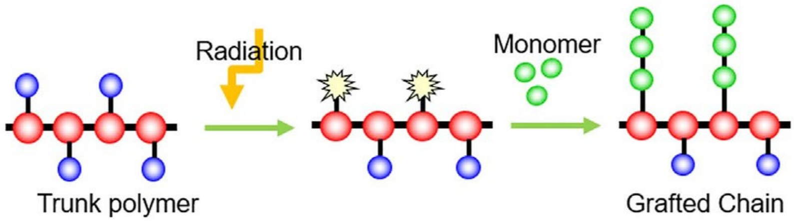


Figure 1: An illustration of processing gamma irradiation grafted on polymer chain [34].

Table 1 shows analysis of modified carbon materials using scanning electron-energy dispersion spectroscopy microscopy (SEM-EDS) results. Commercial carbon has 56.1% weight of carbon (C) and 43.9% oxygen (O). After addition of surfactant sodium lauryl sulphate, analysis result of commercial carbon/SLS showed that the material contains potassium (K) (Figure 2). The addition of SLS as surfactant or surface active agent or emulsifier was able to control carbon particles. In solution, carbon was isotropic and thermodynamically stable emulsions in liquid media. As a result, certain elements in the form of impurities trapped in carbon can be dispersed out of the carbon bulk so that they can be detected. The oxygen concentration on carbon/SLS-irradiated ^{60}Co gamma is the highest between commercial carbon and carbon/SLS. This is result of treatment in the form of exposure to gamma radiation. Gamma radiation causes free radicals such as $OH^{\bullet}$ and $H^{\bullet}$.

Table 1: Analysis result of material carbon using EDS

Element	***%Weight***	***%Error***	***R***	***A***	***F***
Commercial Carbon					
C	56.1	5.3	0.9927	0.9213	1
O	43.9	8	1.0082	0.7437	1
Carbon/SLS					
K	36	6.6	1.0952	1.1845	0.998
C	27	6	0.9832	0.8324	1
O	37	6,5	1	0.9998	1
Carbon/SLS-irradiated ^{60}Co gamma					
K	31	6.4	1.0952	1.1845	0.9998
C	23	5.2	0.9832	0.8324	1
O	46	5	1	0.9999	1

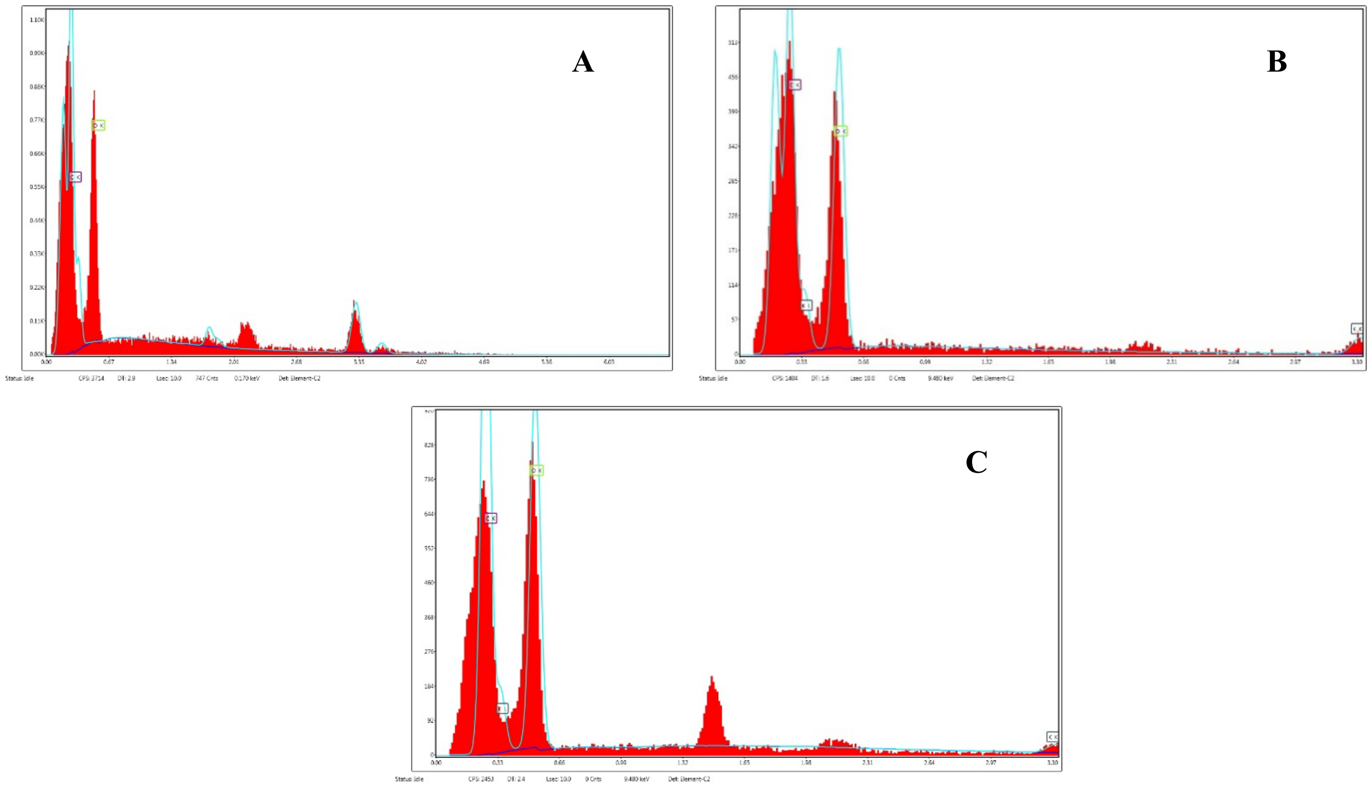
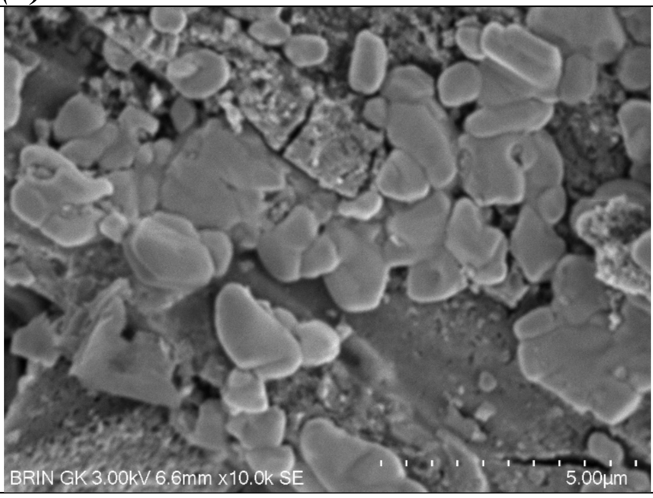


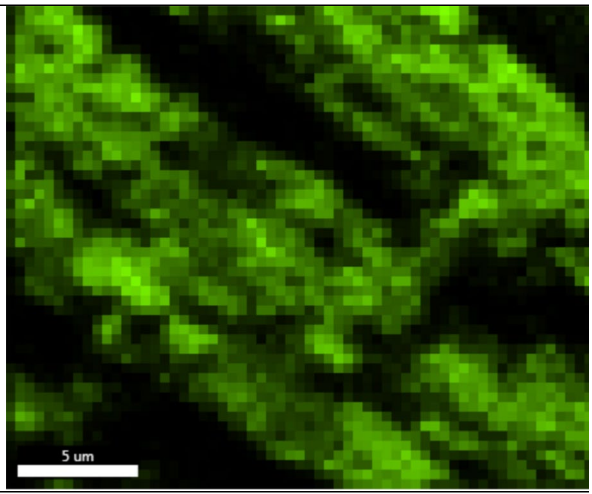
Figure 2: Spectrum analysis of modified carbon materials using energy dispersion spectroscopy (EDS) of (A) Commercial Carbon, (B) Carbon/SLS and (C) Carbon/SLS-irradiated ^{60}Co gamma.

Figure 3 shows morphology of modified carbon. Based on the SEM images in Figure 3, it can be seen that commercial carbon has chunks or bulk form.

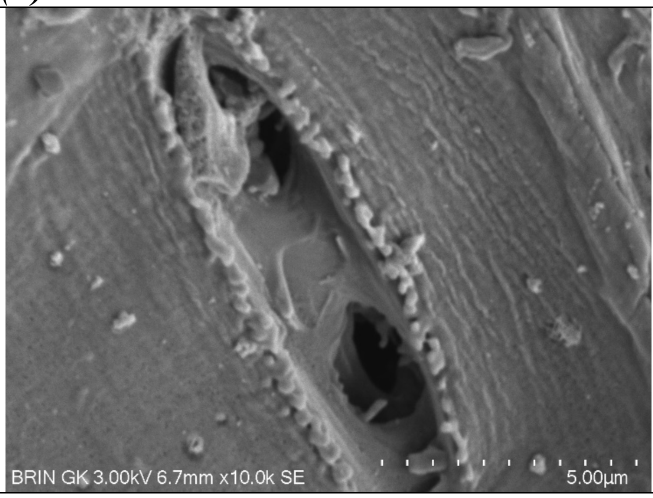
Scanning Electron Microscopy	**Energy Dispersion Spectroscopy**

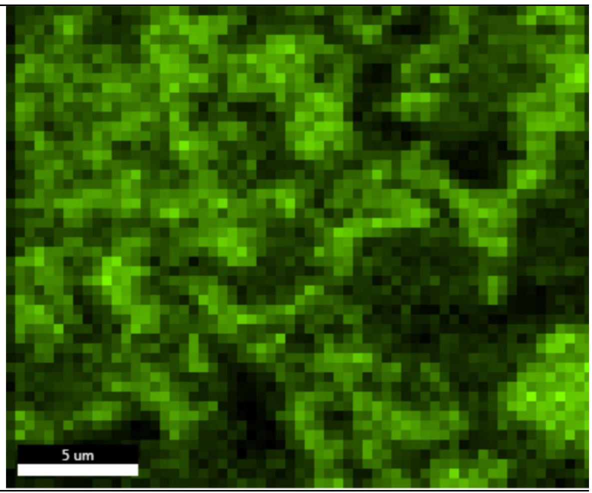
(A)



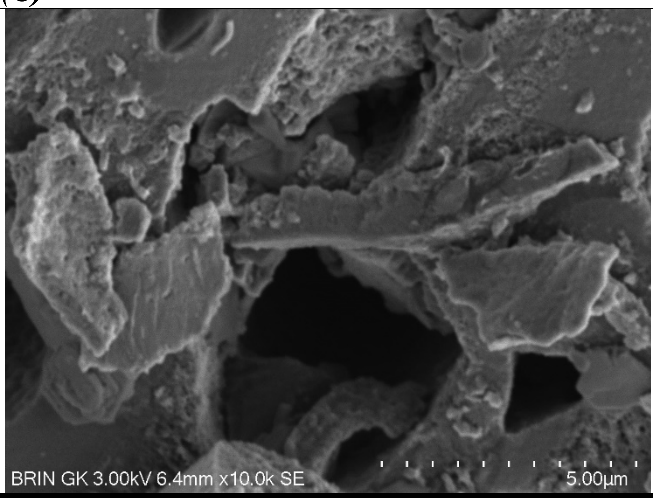


(B)





(C)



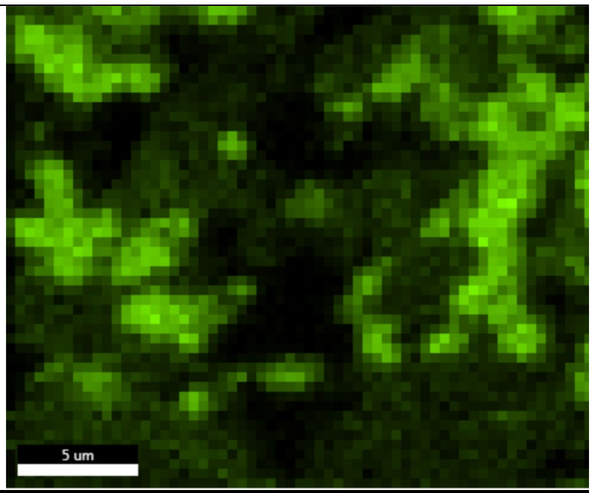


Figure 3: Morphology of modificated carbon (A) Commercial Carbon, (B) Carbon/SLS and (C) Carbon/SLS-irradiated ^{60}Co gamma using scanning electron microscopy (SEM).

After the addition of SLS surfactant, the carbon shape is smoother than commercial carbon. Surfactan prevented agglomerated particles, so it appears to be slightly decomposed so that the lumps will be smaller as shown in the table above. This is possible because surfactants, apart from functioning as stabilizers in the formation of emulsions, will also coat the formed particles so that it will limit bonding of the particles each other because surfactants have hydrophilic and hydrophobic properties. The existence of these surfactant properties causes the carbon particles that are formed not to agglomerate or easily dispersed. Carbon/SLS and carbon/SL-irradiated ^{60}Co gamma has unsmooth surface area, it indicates has good porous and applicable for adsorption. Unsmooth surface area showed that it has more activated group. And it provides more opportunity for adsorbate. In contrast to commercial carbon, which is in the form of chunks and has less active sites, which means it is less applicable for absorption treatment [35].

Conclusions

Based on experiment results, it can be concluded that the effect of irradiation exposure ^{60}Co gamma on the morphology of carbon/SLS is unsmooth particles formation, which indicates that carbon/SLS can be used as adsorbent. Moreover, the presence of surfactant causes the carbon particles not to agglomerate or to be easily dispersed. ^{60}Co gamma irradiation also causes carbon to become rich in oxygen which comes from free radicals.

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Author Contributions

All authors contributed towards data analysis, drafting and critically revsing the paper and agree to be accountable for all aspects of the work.

Disclosure of Conflict of Interest

The authors have no conflict of interest.

Compliance with Ethical Standards

The work is compliant with ethical standards

References

[1] Alatzas, S., Moustakas, K., Malamis, D. & Vakalis, S. (2019). Biomass Potential from Agricultural Waste for Energetic Utilization in Greece. *Energies*. 12, 1095.

[2] Javed, M., Abbas, S., Hussains, S., Siddiq, M., Han, D. & Niu, L. (2018). Amino-functionalized Silica Anchored to Multiwall Carbon Nanotubes as Hybrid Electrode Material for Supercapacitors. *Material Science Energy Technology.* 1, 70-76.

[3] Muller, K., Bugnicourt, E., Latorre, M., Jorda, M., Sanz, Y. & Lagaron, M. (2017). Review on the Processing and Properties of Polymer Nanocomposites and Nanocoatings and their Applications in the Packaging, Automotive and Solar Energy Field. *Nanomaterials.* 7, 74.

[4] Baby, R., Syaifullah, B. & Husseins, M. (2019). Carbon Nanomaterials for the Treatment of Heavy Metal-contaminated Water and Environmental Remediation. *Nanoscale Research Letters*. 1, 14.

[5] Ghasemi, M., Daud, W., Hassan, S., Oh, S., Ismail, M., Rahimnejad, M. & Jahim, J. (2013). Nano-structured carbon as Electrode Material in Microbial Fuel Cells: A Comprehensive Review. *Journal of Alloys and Compounds.* 580, 245–255.

[6] Ghasemi, M., Shahgaldi, S., Ismail, M., Yaakob, Z. & Daud, W. (2012). New Generation of Carbon Nanocomposite Proton Exchange Membranes in Microbial Fuel Cell Systems. *Chemical Engineering Journal.* 184, 82–89.

[7] Ogunlude, P., Abunumah, O., Orakwe, I., Shehu, H., Muhammad-sukki, F. & Gobina, E. (2019). Comparative Evaluation of the Effect of Pore Size and Temperature on Gas Transport in Nano-structured Ceramic Membranes for Biogas Upgrading. *WEENTECH Proceedings in Energy [online].* 5(1)*,* 195–205.

[8] Zhang, Z., Zhu, Z., Shen, B. & Liu, L. (2019). Insights into Biochar and Hydrochar Production and Applications: A Review. *Energy.* 171, 581–598.

[9] Zheng, X., Wang, H., Gong, Q., Zhang, L., Cui, G., Li, Q. & Wang, S. (2015). Highly Luminescent Carbon Nanoparticles as Yellow Emission Conversion Phosphors. *Materials Letters.* 143, 290–293.

[10] Zhu, Z., Rezende, C., Simister, R., McQueen-Mason, S., Macquarrie, D., Polikarpov, I. & Gomez, L. (2016). Efficient Sugar Production from Sugarcane Bagasse by Microwave Assisted Acid and Alkali Pretreatment. *Biomass Bioenergy.* 93, 269–278.

[11] Cui, B., Fenga, X., Zhanga, F., Wang, Y., Liu, X., Yang, Y. & Jia, H. (2017). The Use of Carbon Quantum Dots as Fluorescent Materials in White LEDs. *New Carbon Materials.* 32, 385–401.

[12] Georgakilas, V., Perman, J., Tucek, J. & Zboril, R. (2015). Broad Family of Carbon Nanoallotropes: Classification, Chemistry, and Applications of Fullerenes, Carbon Dots, Nanotubes, Graphene, Nanodiamonds, and Combined Superstructures. *Chemical Reviews.* 115, 4744–4822.

[13] Rui, X., Li, M., Song, J., Shen, Z. & Zeng, H. (2015). Carbon and Graphene Quantum Dots for Optoelectronic and Energy Devices: A Review. *Advanced Functional Materials.* 25, 4929–4947.

[14] Zheng, X., Wang, H., Gong, Q., Zhang, L., Cui, G., Li, Q. & Wang, S. (2015). Highly luminescent Carbon Nanoparticles as Yellow Emission Conversion Phosphors. *Materials Letters.* 143, 290–293.

[15] Chaikittisilp, W., Hu, M., Wang, H., Huang, H., Fujita, T., Wu, C. & Ariga, K. (2012). Nanoporous Carbons Through Direct Carbonization of a Zeolitic Imidazolate Framework for Supercapacitor Electrodes. *Chemical Communications.* 48, 7259–7261.

[16] Rad, T., Ansarian, Z., Khataee, A., Vahid, B. & Doustkhah, E. (2021). N-doped Graphitic Carbon as A Nanoporous MOF-derived Nanoarchitecture for the Efficient Sonocatalytic Degradation Process. *Separation and Purification Technology.* 256, 117811.

[17] Marpaung, F., Kim, M., Khan, J., Konstantinov, K., Yamauchi, Y., Hossain, S. & Kim, J. (2019). Metal–organic Framework (MOF)-derived Nanoporous Carbon Materials. *Chemistry—An Asian Journal.* 14, 1331–1343.

[18] Kim, J., Kim, S. & Kim, D. (2013). Energy Harvesting from Salinity Gradient by Reverse Electrodialysis with Anodic Alumina Nanopores. *Energy.* 51, 413–421.

[19] Sun, X., Liu, Y., Xu, R. & Chen, Y. (2022). MOF-derived Nanoporous Carbon Incorporated in the Cation Exchange Membrane for Gradient Power Generation. *Membranes.* 12, 322.

[20] Zhang, X., Tong, Z., Liu, C., Ye, L., Zhou, Y., Meng, Q. & Gao, C. (2022). Functionalized MOF-Derived Nanoporous Carbon as Compatible Nanofiller to Fabricate Defect-Free PDMS-Based Mixed Matrix Pervaporation Membranes. *ACS Omega.* 7, 15786–15794.

[21] Madurani, K. A., Suprapto, Machrita, N. I., Bahar, S. L., Illiya, W. & Kurniawan, F. (2020). Progress in Graphene Synthesis and its Application: History, Challenge and the Future Outlook for Research and Industry. *ECS Journal of Solid State Science and Technology.* 9(9), 1-13.

[22] Fathy, N., Basta, A. & Lotfy, V. (2020). Chapter 4—Novel Trends for Synthesis of Carbon Nanostructures from Agricultural Wastes. In *Carbon Nanomaterials for Agri-Food and Environmental Application; Micro and Nano Technologies.* Ed. Kamel, A. A. (Elsevier, Amsterdam) pp. 59–74.

[23] Ding, M., Chen, G., Xu, W., Jia, C. & Luo, H. (2019). Nano Materials Science Bio-inspired Synthesis of Nanomaterials and Smart Structures for Electrochemical Energy Storage and Conversion. *Nano Materials Science.* 2, 264–280.

[24] Ghosh, S., Santhosh, R., Jeniffer, S., Raghavan, V., Jacob, G., Nanaji, K. & Graceet, A. (2019). Natural Biomass Derived Hard Carbon and Activated Carbons as Electrochemical Supercapacitor Electrodes. *Scientific Reports.* 9, 16315.

[25] Li, Z., Bai, Z., Mi, H., Ji, C., Gao, S. & Pang, H. (2019). Biowaste-derived Porous Carbon with Tuned Microstructure for High-energy Quasi-solid-state Supercapacitors. *ACS Sustainable Chemistry & Engineering.* 7, 13127–13135.

[26] Xiong, B., Li, H. & Xiao, Y. (2020). Progress on Synthesis and Applications of Porous Carbon Materials. *International Journal of Electrochemical Science.* 15, 1363–1377.

[27] Jirimali, H., Singh, J., Boddula, R., Lee, J.-K. & Singh, V. (2022). Nano-Structured Carbon: Its Synthesis from Renewable Agricultural Sources and Important Applications. *Materials.* 15*(*11), 1-24.

[28] Liu, Y., Liu, S., Li, Z., Ma, M. & Wang, B. (2018). A Microwave Synthesized Mesoporous Carbon Sponge as An Efficient Adsorbent for Cr(VI). *RSC Advances.* 8, 7892–7898

[29] Liu, Z., Huang, Y. & Zhao, G. (2016). Preparation and Characterization of Activated Carbon Fibers from Liquefied Wood by ZnCl2 Activation. *BioResources.* 11, 3178–3190.

[30] Al-Latief, D. N., Arnelli & Astuti, Y. (2015). Synthesis of Sodium Lauryl Sulphate (SLS)-Modified Activated Carbon from Risk Husk for Waste Lead (Pb) Removal. AIP Conference Proceedings, Indonesia, 29-30 September 2015.

[31] Anisyah, A., Arnelli, A. & Astuti, Y. (2021). Pembuatan Karbon Aktif Termodifikasi Surfaktan Sodium Lauryl Sulphate (SMAC-SLS) dari Tempurung Kelapa Menggunakan Aktivator ZnCl2 dan Gelombang Mikro sebagai Adsorben Kation Pb(II). *Greensphere: Journal of Environmental Chemistry.* 1(1), 1-6.

[32] Arnelli, A., Wahyuningrum, V. N., Fauziah, F. & Astuti, Y. (2019). Synthesis of Surfactant Modified Activated Carbon (SMAC) from Rice Husks as Ni(II) and Cr(VI) Adsorbent. *IOP Conference Series: Materials Science and Engineering.* 509, 1-8.

[33] Walo, M. (2022). Radiation-Induced Grafting. In *Applications Of Ionizing Radiation In Materials Processing*, vol. 2. Ed. Yongxia S. & Andrzej G. C. (Institute of Nuclear Chemistry and Technology, Warszawa), pp. 193-210.

[34] Naikwadi, A. T., Sharma, B. K., Bhatt, K. D. & Mahanwar, P. A. (2022). Gamma Radiation Processed Polymeric Materials for High Performance Applications: A Review. *Frontiers in Chemistry.* 10, 1-15.

[35] Nowruzi, R., Heydari, M. & Javanbakht, V. (2020). Synthesis of a Chitosan/Polyvinyl Alcohol/Activate Carbon Biocomposite for Removal of Hexavalent Chromium from Aqueous Solution. *International Journal of Biological Macromolecules.* 147, 209–216.