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EDITORIAL

Special issue: CO_2: capture of, utilization of, and degradation into

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Carbon dioxide (CO_2) capture and utilization have been challenging issues in the field of polymer science. Due to the steady increase in CO_2 concentration in the atmosphere and its potential threat as a Greenhouse gas, numerous efforts have been devoted to the development of polymer membranes for CO_2 capture in the past few decades. CO_2 is generally recognized as an inert gas, but can react with other reagents and catalysts. Indeed, a variety of polymerization processes with CO_2 as a raw material have been developed since the pioneering work on epoxide/CO_2 copolymerization by Prof. Inoue et al. Recent studies have also demonstrated that biosynthesis is an attractive and promising process to prepare functional polymer materials from CO_2. These CO_2-derived polymer materials store the carbon from CO_2 in a certain period and then release it as CO_2 by combustion or biodegradation. Accordingly, the coupling of CO_2 capture, CO_2 utilization, and degradation into CO_2 can close the carbon cycle, contributing to the next-generation polymer engineering for a circular economy. Considering the environmental pollution issues, including microplastics in the ocean, degradation of polymeric materials into CO_2 is also an essential science to realize the sustainable society. In this context, we organized a diverse team consisting of the Editor-in-Chief, an associate editor, and guest editors to publish this special issue on CO_2-related polymer science.

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In this special issue, the chemical synthesis of CO_2-based polymers is one of the hot topics as a typical utilization of CO_2. Meng et al. reviewed the syntheses of CO_2-based copolymers with cyclic anhydrides and cyclic esters [1]. Darensbourg et al. reported copolymerization to synthesize completely alternating regioregular ^{13}C-labelled poly(propylene carbonate) [2]. Kerton et al. reviewed iron-catalyzed reactions of CO_2 and epoxides to synthesize cyclic and polycarbonates [3]. Sugimoto et al. reported terpolymerization of CO_2, propylene oxide, and various epoxides with bulky side groups to tune the resultant copolymers' thermal properties [4]. Nakano et al. reported the synthesis of polycarbonate-block-polycycloalkenes via epoxide/CO_2 copolymerization and ring-opening metathesis polymerization [5]. Tominaga et al. reported ion-conductive and dielectric behavior of poly(ethylene carbonate)-based Li electrolytes [6]. For the CO_2 capture, several membranes for CO_2 separation are introduced in this issue. Taniguchi et al. reported piperazine-immobilized polymeric membranes for CO_2 capture [7]. Matsuyama et al. reported inorganic/organic double-network ion gel membrane for CO_2 separation [8]. Yamada et al. overviewed recent progress of the development of carbon capture process and amine-based CO_2 capture technologies [9]. Hoshino et al. reported thermo-responsive CO_2 absorbent for high and low concentration CO_2, which functions by tuning pK_a of ammonium ions [10]. Fujikawa et al. reviewed the general understanding of the polymeric membranes for CO_2 capture and separation [11]. Biodegradable polymers are also essential and target topics in this special issue. Sudesh et al., Tsuge et al., Kasuya et al., Taguchi et al., and Mota et al. reported biosynthesis and biodegradation of polyhydroxyalkanoates [12–16]. Another bacterial polymer, cyanobacterial polysaccharides, is also reviewed by Kaneko et al. [17]. As other biodegradable and biological polymers, Fujisawa et al. reported cellulose and its composites [18]. Numata et al. reported silk materials as biological and biodegradable materials [19].

We believe that this special issue will be valuable for readers who have scientific and practical interests in CO_2-related polymer science and contribute to significant advances

in this area in the future. Finally, we sincerely appreciate all authors and referees for their contribution to this special issue.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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References

1. Liang J, Ye S, Wang S, Xiao M, Meng Y. Design and structure of catalysts: syntheses of carbon dioxide-based copolymers with cyclic anhydrides and/or cyclic esters. Polym. J. https://doi.org/10.1038/s41428-020-0374-1.
2. Bhat GA, Darensbourg MY, Darensbourg DJ. Copolymerization of propylene oxide and $^{13}CO_2$ to afford completely alternating regioregular ^{13}C-labelled Poly(propylene carbonate). Polym. J. https://doi.org/10.1038/s41428-020-0391-0.
3. Andrea KA, Kerton FM. Iron-catalyzed reactions of CO_2 and epoxides to yield cyclic and polycarbonates. Polym. J. https://doi.org/10.1038/s41428-020-00395-6.
4. Honda M, Ebihara T, Ohkawa T, Sugimoto H. Alternating terpolymerization of carbon dioxide, propylene oxide, and various epoxides with bulky side groups for the tuning of thermal properties. Polym. J. https://doi.org/10.1038/s41428-020-00412-8.
5. Nakabayashi Y, Nakano K. Polycarbonate-block-polycycloalkenes via epoxide/carbon dioxide copolymerization and ring-opening metathesis polymerization. Polym. J. https://doi.org/10.1038/s41428-020-00423-5.
6. Kobayashi K, Pagot G, Vezzù K, Bertasi F, Noto VD, Tominaga Y. Effect of plasticizer on the ion-conductive and dielectric behavior of poly(ethylene carbonate)-based Li electrolytes. Polym. J. https://doi.org/10.1038/s41428-020-00397-4.
7. Taniguchi I, Kinugasa K, Toyoda M, Minezaki K, Tanaka H, Mitsuhara K. Piperazine-immobilized polymeric membranes for CO_2 capture: mechanism of preferential CO_2 permeation. Polym. J. https://doi.org/10.1038/s41428-020-0389-7.
8. Kamio E, Minakata M, Iida Y, Yasui T, Matsuoka A, Matsuyama H. Inorganic/organic double-network ion gel membrane with a high ionic liquid content for CO_2 separation. Polym. J. https://doi.org/10.1038/s41428-020-0393-y.
9. Yamada H. Amine-based capture of CO_2 for utilization and storage. Polym. J. https://doi.org/10.1038/s41428-020-00400-y.
10. Honda R, Hamasaki A, Miura Y, Hoshino Y. Thermoresponsive CO_2 absorbent for various CO_2 concentrations: tuning the pK_a of ammonium ions for effective carbon capture. Polym. J. https://doi.org/10.1038/s41428-020-00407-5.
11. Fujikawa S, Selyanchyn R, Kunitake T. A new strategy of membrane-based direct air capture. Polym. J. https://doi.org/10.1038/s41428-020-00429-z.
12. Hairudin NHBM, Ganesan S, Sudesh K. Revalorization of adsorbed residual oil in spent bleaching clay as a sole carbon source for polyhydroxyalkanoate (PHA) accumulation in Cupriavidus necator Re2058/pCB113. Polym. J. https://doi.org/10.1038/s41428-020-00418-2.
13. Thorbecke R, Yamamoto M, Miyahara Y, Oota M, Mizuno S, Tsuge T. The gene dosage effect of carbonic anhydrase on the biosynthesis of poly(3-hydroxybutyrate) under autotrophic and mixotrophic culture conditions. Polym. J. https://doi.org/10.1038/s41428-020-00409-3.
14. Suzuki M, Tachibana Y, Kasuya K. Biodegradability of poly(3-hydroxyalkanoate) and poly(ε-caprolactone) via biological carbon cycles in marine environments. Polym. J. https://doi.org/10.1038/s41428-020-00396-5.
15. Taguchi S, Matsumoto K. Evolution of polyhydroxyalkanoate synthesizing systems toward a sustainable plastic industry. Polym. J. https://doi.org/10.1038/s41428-020-00420-8.
16. Castro LM, Foong CP, Higuchi-Takeuchi M, Morisaki K, Lopes EF, Numata K, Mota AJ. Microbial prospection of an Amazonian blackwater lake and whole-genome sequencing of bacteria capable of polyhydroxyalkanoate synthesis. Polym. J. https://doi.org/10.1038/s41428-020-00424-4.
17. Okeyoshi K, Okajima MK, Kaneko T. The cyanobacterial polysaccharide sacran: characteristics, structures, and preparation of LC gels. Polym. J. https://doi.org/10.1038/s41428-020-00426-2.
18. Fujisawa S. Material design of nanocellulose/polymer composites via Pickering emulsion templating. Polym. J. https://doi.org/10.1038/s41428-020-00408-4.
19. Chen J, Ohta Y, Nakamura H, Masunaga H, Numata K. Aqueous spinning system with a citrate buffer for highly extensible silk fibers. Polym. J. https://doi.org/10.1038/s41428-020-00419-1.