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A comprehensive review on modified clay based composite for energy based materials

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ABSTRACT

The interest in porous clay and its modification has been exponentially increasing. The outstanding properties of clay were evident due to high thermal and chemical resistance, as well as high porosity. By virtue of these reasons, modified clay was therefore prepared from many synthetic routes for significant enhancement on specific surface area and porosity. The application of modified clay was versatile in many areas of industrial commercialization. It was related to catalyst support, separation technology, electronic device as well as food packaging. To use modified clay with higher efficiency, it was consequently designed as composite based materials. Small amount of modified clay from chemical synthetic route was therefore integrated into polymer matrix. To be challenge on the use of modified clay based composite, it was investigated for being as energy storage materials. Due to high thermal resistance along with excellent specific surface area and porosity, modified clay was therefore gained many interests. Modified clay based composite will be employed as energy based material with additional feature of flexibility.

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1. Overview

In recent year, concern over the shortage of petroleum and petrochemical based materials and the ever growing issue of global waste, along with rising oil prices and the pending exhaustion of landfills, has created a demand for research and development of eco-friendly materials. As a consequence, numerous bio-based materials have been extremely developed in order to replace on the use of petroleum and petrochemical products [1–9]. The research of bio-based materials was versatile starting from the development from renewable and sustainable resource to the modification on structure and surface properties in order to tailor in many performances. The type of bio-based materials can be categorized into bio-based ceramic and

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bio-based polymer. The example of bio-based materials was therefore cellulose and its derivatives, chitin-chitosan based materials, lignin and its modified structure. Most of them were considered as bio-based polymer which was commonly provided many benefits in terms of available resource. Moreover, bio-based materials can be extended many types of bio-based synthetic route. The example was due to bacterial cellulose, which was commonly derived from the fermentation of some bacterial specie [11,12]. On the other hand, the other type of bio-based materials was considered on bio-based ceramic. The example of bio-based ceramic was due to alumina powder, porous clay heterostructure as well as zeolite [4,7]. To gain many advantages on the use of bio-based materials, numerous techniques have been employed in order to tailor its properties. The example of improvement technique was due to physical and chemical modification technique, surface modification as well as the design of bio-based composite.

Within a decade, our research group was successfully developed many types of bio-based material and investigated on the feasibility to be reality in many engineering sectors. The challenge of our group was due to the development of porous clay heterostructure from bentonite and its investigation as absorption media in active packaging [4,13–15]. From the fundamental point of view, clay, which belongs to the phyllosilicate group, was considered as a versatile material with a wide range of application. The example of application of clay based materials was due to absorbent media, ion exchangers, catalyst as well as paper coating. The performance of clay in this application was controlled by the physicochemical properties of clays as well as the way to modify to being as clay based composite [16–18]. Up to the present time, numerous approaches have been extensively developed and it was resulted in modified clay that has been received a considerable attention from many past decades [19,20]. From the structural point of view, pillared interlayered clay was considered as a well-known family of microporous and mesoporous materials. As a result, it was successfully modified by multi-step of molecular engineering processes. To gain more specific surface area of modified clay, it was modified by surfactant template methods, or it can be modified by insertion of pillaring agents which can be extent on the interlayer space. The example of pillaring agent was due to organic, organometallic and inorganic complex [21–23]. The role of pillaring agent led to a two-dimensional channel system with high porous structure. The benefit of specific surface area enhancement was due to ability to be absorbed or being a host–guest material. From the fundamental point of view, the role of specific surface area enhancement can be prepared according to surfactant template based method. Cationic surfactant was employed and the other reason was due to mineral clay itself. Clay exhibits the strong potential on the cationic ion exchange. On the other hand, the other reason was due to silica source, it was easy to be reacted and subsequently formed the inter-bonding of clay network. The example of silica source was due to tetraethoxysilane and etc. It can be reacted on the surface of clay and subsequently enhanced on surface area properties.

After specific surface area enhancement, it can gain many approaches on numerous engineering sectors. The example of modified application was commonly referred to waste water treatment, chemical and hazardous sensor, active packaging as well as electronic.

In the last decades, our research group was focused on the development of dielectric based materials. The role of dielectric based material was versatile. It can be enrolled in capacitive based material, electro-mechanical device as well as chemical sensor. From the fundamental point of view, dielectric material was theoretically referred to insulators, which means that no current flow through the material when a voltage was applied [24–27]. However, certain change occurred at the atomic scale; when a voltage was applied across a dielectric material, it subsequently became polarized. It can be noted that since atoms were made of a positively charged nucleus and negatively charged electronic, polarization was considered as an effect which slightly shifted electron towards the positive voltage. It was not enough to create a current flow through material. In general, the change on movement of electronic charge was considered at microscopic level, but it provided an important effect, especially when dealing with macroscopic level. The effort of dielectric materials was versatile in many areas of research. Once the voltage source is removed from the material, it either returns to its original non-polarized state, or stays polarized if the molecular bonds in the material are weak. The difference between the terms dielectric and insulator is not very well defined. All dielectric materials are insulators, but a good dielectric is one which is easily polarized. The amount of polarization which occurs when a certain voltage is applied to an object influences the amount of electrical energy that is stored in the electric field. This is described by the dielectric constant of the material. The dielectric constant is not the only property of dielectric materials. Other properties such as dielectric strength and dielectric loss are equally important in the choice of materials for a capacitor in a given application.

Up to the present time, it was remarkable to note that the role of clay gained many interests on both academic and industrial research. Due to the excellent performance on its chemical and thermal resistance, clay has been extensively modified for many prospective applications. In this review, many successful process of modified clay have been presented. Clay was successfully modified by physical and chemical method. The development of clay based composite has been prepared. The objective of this review article was to give the overview on modified clay based composite. The content was covered on the modification of clay from natural resource to an approach on energy based materials. The example of energy based materials was involved on dielectric materials, fuel cell technology, membrane technology, battery.

2. Theoretical background on clay and its modification

Porous clay has been extensively investigated on the structure and it was important to note that the role of porous clay has been employed in numerous sectors of both academic research and industry. In order to understand the importance of porous clay in research, the structure and physical properties of porous clay should be declared [28].

From the structural point of view, porous clay was considered as inorganic particles belong to the family of 2:1 phyllosilicates. It was therefore noted that the crystal structure of porous clay consisted of an aluminium and magnesium hydroxide octahedral sheet sandwiched between two silicon oxide tetrahedral sheets. The view point on the use of porous clay was versatile. Some part of research studies the sheet and called it as platelet of silica. In general, the layer thickness of each silica platelet was estimated to be 1 nm, and its lateral dimensions were varied from 30 nm to several micron range. It was important to note that structure of porous clay was considered similar to many pages of book. The Van der Waals gaps were created between the layers, called galleries. The isomorphic substitution of the tetrahedral or octahedral cations such as the substitution of $Al^{3+}$with Mg^{2+}or $Fe^{2+}$with Li^{1+}, generates negative charges that are counterbalanced by alkali and alkaline earth cations located inside the galleries. In the case of tetrahedral substitution, the negative charge is located on the surface of the silicate layers and, thus, the polymer matrices can interact more readily with tetrahedral than with octahedral substituted material [29,30].