Egyptian Journal of Petroleum (2016) 25, 281–291

HOSTED BY

ELSEVIER

Egyptian Petroleum Research Institute

Egyptian Journal of Petroleum

www.elsevier.com/locate/egyjp
www.sciencedirect.com

FULL LENGTH ARTICLE

High performance nature of biodegradable polymeric nanocomposites for oil-well drilling fluids

Tarek M. Madkour [a], Samar Fadl [a], M.M. Dardir [b,*], Mohamed A. Mekewi [c]

[a] *Department of Chemistry, The American University in Cairo, New Cairo 11835, Egypt*
[b] *Drilling Fluids Laboratory – Production Department, The Egyptian Petroleum Research Institute, EPRI, Egypt*
[c] *Department of Chemistry, Faculty of Science, Ain-Shams University, Cairo, Egypt*

Received 21 May 2015; revised 30 August 2015; accepted 2 September 2015
Available online 22 December 2015

KEYWORDS

Polymeric nanocomposites;
Poly(lactic acid) (PLA);
Drilling fluids

Abstract Multi-walled carbon nanotube (MWCNT) and graphene nanoplatelet reinforced thermoplastic poly(lactic acid) (PLA) biodegradable nanocomposites were designed and prepared using solution casting techniques. The prepared biodegradable polymers are expected to provide an environmentally friendly alternative to petroleum-based polymers. Both nanocomposite systems exhibited better thermal stability and improved mechanical performance over the unreinforced polymer exhibiting excellent strength and degradability. The addition of graphene nanofiller in varied amounts was aimed to enhance the thermal and mechanical properties of the nanocomposites even further and incorporate the outstanding characteristics of graphene nanoplatelets into the nanocomposites. The polymeric nanocomposites showed also superior advantages for oil drilling relevances, automotive lubricating purposes, membrane technology and food packaging. Scanning electron microscopy images indicated a homogeneous dispersion of the nanofiller within the polymeric matrix at low filler loadings and a cluster formation at higher loadings that could be responsible for the polymeric matrix movement restrictions. The enthalpy of mixing (the polymer and the nanofiller) measured could explain the cause of the repulsive interactions between the nanoparticles and the polymeric chains, which created an additional excluded volume that the polymeric segments were restricted to occupy, thus forcing the conformational characteristics of the polymeric chains to deviate away from those of the bulk chains. The prepared polymeric nano composites (poly lactic acid carbon nano tube and poly lactic acid graphene nanoplatelets) were utilized in the formulation of oil-base mud as a viscosifier. The rheological, filtration properties and electrical stability of the oil based mud formulation with the new polymeric nanocomposite were studied and the result compared to the oil-based mud formulation with commercial viscosifier.

1. Introduction

The majority of plastic materials used nowadays are based on fossil raw materials. Packaging materials are produced in huge

* Corresponding author.
E-mail address: monamdardir@yahoo.com (M.M. Dardir).
Peer review under responsibility of Egyptian Petroleum Research Institute.

http://dx.doi.org/10.1016/j.ejpe.2015.09.004
1110-0621

amounts yearly and they are discarded after the product has been used, which contributes to growing landfills and enhanced greenhouse effects [1]. Due to the limited fossil fuel resources and the impact of petroleum-based materials on the environment, there is a huge undertaking by scientists and engineers to replace those materials by biological alternatives, which indicates the ongoing trend of a sustainable development in the near future [2]. The use of bio-nanocomposites for oil drilling, automotive lubricating purposes, membrane technology and food packaging has the potential to provide an environmentally friendly solution since it helps in the management of the world's waste problem and reduces the requirement for using petroleum-based plastics as packaging materials [3]. Most of the traditional petroleum-based packaging materials are made from non-degradable materials, which also increase environmental pollution in addition to consuming fossil fuels for their production. However, alternative biodegradable films are currently exhibiting poor barrier and mechanical properties, which need to be improved considerably before they are considered as a sound replacement for traditional plastics [4]. However, there are major concerns regarding the mechanical, thermal and barrier properties of the natural biopolymer-based packaging materials [5]. One way to improve the quality of these biodegradable and biorenewable polymers is to use nanocomposites based on these natural polymers that exhibit improved mechanical, thermal and gas barrier properties [6–8]. In an attempt to overcome these limitations, nanoclays have been used as supportive filling agents in a biopolyester matrix where they formed nanocomposite structures [9–11]. Cabedo et al. [9] showed that the addition of nanoclay such as kaolinite nanofillers to PLA films improved both their thermal stability and mechanical properties without decreasing barrier properties. The most important properties of materials are mechanical properties, thermal properties and gas barrier properties. Biodegradable polymers can be recovered through composting and returned to nature [12].

In recent years, composting is considered as the preferred method of treatment of organic solid waste, and this is where the biodegradable/compostable bioplastics are supposed to end up. Hence, compostable polymers especially derived from renewable resources are being promoted and known as environmentally beneficial materials for various industries [12]. It is challenging to be able to replace the conventional materials with bio-based ones. Another challenge is biodegradability which has to perform efficiently on disposal. Degradability can on one hand constrain biopolymer applications to short-term use, and on the other hand facilitate composting. There are several factors, such as water activity, microorganisms, temperature, composition of biomaterial, etc., which affect biodegradation as well as deterioration rate and must be considered in the various applications.

Biopolyesters have promising properties such as excellent transparency and cellophane-like mechanical properties. Blown films in commercial use are developed based on biodegradable polyesters, which do not contain six-carbon rings known as aliphatic polyesters such as poly(caprolactone) (PCL), poly(glycolic acid) (PGA) and poly(butylene succinate) (PBS). However, regarding the other requirements of a barrier film, it is believed that no single bio-based polymer can be both water vapor and gas barrier. Therefore, in this case, the use of co-extrusion can lead to laminates which meet the requirements [13]. Another class of products is thermoformed polymers. In order to thermoform a polymer, there should be a possibility to process the material from the melt (extrusion) into sheets and to thermoform the sheets just above the softening temperature of the material. Possible examples are biopolymers based on PLA and PHB/V (Poly Hydroxy Butyrate/Valerate), paragon laminates and also other thermoplastically processable biopolymers. Gas barriers of packaging materials become essential when the gas composition inside the package has to be kept constant [14–19]. The gas combination of packaging products is mostly CO_2, O_2 and N_2. There are also products that require specific atmospheric conditions during storage; therefore, they are packed in protective atmosphere with specific mixture of gases. Hence, the permeability of oxygen and other gases, which are closely interrelated, must be engineered and are desired to be low [19]. A material with lower oxygen permeability (OP) than 10 $cm^3.\mu m/m^2.day.kPa$ is considered to be a good oxygen barrier [15]. Many polysaccharides (natural polymeric carbohydrates) are known to be good oxygen barriers, explained by their hydrogen-bonded network which leads to small free volume that makes the oxygen transmission low [16]. In fact, biopolymers are able to mimic the oxygen permeability of a wide range of the conventional petroleum-based materials [17,18]. Humidity is another important parameter interfering in gas barrier properties. With increasing humidity gas permeability increases for both bio-based polymers and conventional ones, even high gas barrier materials such as nylon and ethylvinyl alcohol have a lower barrier performance in humid conditions. In order to manufacture appropriate materials for various applications, it is unlikely that just one polymer can have all properties. Therefore, employing multiple materials in a composite or use of nanocomposites might be necessary, which can fulfill high demands such as very low gas permeability, high water resistance, etc. A similar multi-layer approach can also be used for bio-based polymers.

Drilling fluids or drilling muds are an essential and a key component of the rotary drilling process used to drill for oil and gas on land and in offshore environment. The most important functions of drilling fluids are to transport cutting to the surface, to balance subsurface, cool, lubricate and support part of the weight drill bit and drill pipe [20–25]. Although the high toxicity of oil-based mud it is used when drilling deep wells due to its high performance and high thermal stability than water based-mud and also it is less expensive than synthetic based mud. Oil-based muds (OBM) don't hydrate the shell and maintain hole stability wells drilled with OBM which normally produce lower waste values than those drilled with water-based muds (WBM) because a nearly gauge hole is drilled and the mud is conditioned. Oil-based muds which are formulated with crude oil or diesel oil are excellent for inhibiting water – sensitive shell and clays extended reach – wells, highly density formation and drilling through salt [26–28].

Most oils lack many qualities necessary in drilling operations, for example, most crude petroleum oils of low density are inflammable, leading last the permeable formations and lack the required viscosity and gel strength property. Numerous means usually involve adding materials such as blown asphalt or other finely divided solids to the oil to increase the density, viscosity and gel strength and to give the fluid plastering properties to decrease loss of the fluid to permeable formation. Most of these materials are viscosifiers agent. The term oil-base drilling fluids has been as a system, the