

Exploring the Role of $\text{Mg}(\text{OH})_2$ in Enhancing Flame Retardancy and Tensile Strength of PP/POE Blends

Kosar Sayadi

Kosar.saya@aut.ac.ir

Amirkabir University of Technology

Research Article

Keywords: Flammability, mineral filler, polypropylene, flame retardant, magnesium hydroxide, limiting oxygen index (LOI)

Posted Date: September 19th, 2025

DOI: <https://doi.org/10.21203/rs.3.rs-7113572/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

What about addressing potential challenges related to the dispersion and compatibility of magnesium hydroxide ($\text{Mg}(\text{OH})_2$) within the PP/POE blends, and how might this affect the flame retardancy and tensile strength?

Polypropylene (PP) is one of the five plastics widely used in many fields due to its high strength and crystallinity. Polypropylene (PP) burns very quickly due to its completely aliphatic hydrocarbon structure, which limits its scope of application. The use of flame retardant additives in polypropylene (PP) is necessary to minimize the risk of fire due to its inherent flammability. Various types of flame retardants, including halogen, phosphorus, and inorganic compounds, are used due to their flame retardant properties. Magnesium hydroxide typically acts as a flame retardant, producing water to dilute flammable gases. These mineral fillers act in the dense phase and reduce the rate of mass loss and heat release during combustion. This research aims to investigate the effect of magnesium hydroxide ($\text{Mg}(\text{OH})_2$, MDH) on the tensile properties and limiting oxygen index (LOI) of polypropylene (PP)/ethylene-butene copolymer (POE) blends.

Introduction

Polymers, particularly synthetic ones, are highly flammable and pose significant fire hazards, contributing to numerous fatalities and property losses annually (1, 2). The flammability of polymers limits their application in advanced materials and systems (3). To address this issue, various flame retardant methods have been developed (3). These flame retardant methods aim to achieve high efficiency, and durability and reduce the emission of heat, smoke, and toxic gas without compromising the overall properties of the polymers (3).

Polypropylene (PP) is a versatile, cost-effective plastic with excellent mechanical properties, widely used in various industries (4). Its global production is expected to reach 88 million tons by 2026 (5). PP is widely used in various industries such as fabrics, bottles, auto parts medical equipment, etc. (4, 6). PPs are emerging as sustainable alternatives to traditional fossil fuel-derived plastics (5).

This growing demand shows the importance of PP for applications where low density, hardness, high flexural modulus, and chemical resistance are required (7, 8). In addition, PP is a low-cost plastic that can be processed by various methods such as extrusion, thermoforming, and injection molding (8, 9).

The widespread use of synthetic polymers has significantly increased fire risks in various environments (1, 10). Synthetic polymers are generally more flammable than natural ones, with some having calorific values comparable to petroleum (1). Fire hazards associated with polymers involve multiple factors, including ignitability, flammability of volatile products, heat release, and smoke toxicity (2).

Fillers have played a crucial role in polymer development, initially used to reduce costs but now primarily to enhance properties (11). As polymers became less expensive, the focus shifted to using fillers to

modify and improve polymer characteristics for various applications (12).

When solid substances undergo thermal treatment, alterations in both physical and chemical properties manifest at specific temperatures, which are contingent upon the chemical makeup of the solid substance. Thermoplastic polymers exhibit softening behavior at the glass transition temperature and subsequently undergo melting at an elevated temperature (T_m), wherein they chemically decompose into lower molecular weight fragments. The initiation of chemical transformations commences at T_p and persists until the temperature threshold for combustion (T_c) is reached. These four temperature parameters are critically significant when assessing the flame resistance characteristics of fibers. Another parameter in the field of combustion is the limiting oxygen index (LOI). This index quantifies the requisite concentration of oxygen within the fuel composition to sustain combustion. An increase in this numerical value indicates a higher difficulty in achieving ignition. For thermoset polymers, the values of (T_p) or (T_c) are lower than those of (T_g) or (T_m), whereas for thermoplastics, the values of (T_p) or (T_c) surpass those of (T_g) or (T_m) (13).

The byproducts of combustion vary depending on the specific combustible composition. In the instance of polymers, the primary combustion gases are carbon dioxide (CO_2), carbon monoxide (CO), and water vapor (H_2O). The residual solid matter predominantly consists of carbon (C) and ash (which contains oxidized metals). A flame retardant system refers to a compound or a combination of compounds incorporated into materials to enhance their resistance to combustion. This flame retardant system may be introduced during the polymer synthesis phase, during the primary mixing of polymer additives, or throughout the manufacturing of plastic products (13).

The combustion characteristics of a conventional polymer substrate are intrinsically linked to its molecular structure. Consequently, comprehending the interaction between a polymeric substance and an ignition source is paramount in the formulation of a proficient fire-retardant strategy. Generally, when combustible materials are subjected to a designated thermal or fire source under standard environmental conditions, sustained and rapid oxidative reactions transpire with the aid of a continuous supply of adequate oxidizing or other combustion-facilitating gases. The combustion process serves to catalyze the polymer's chain reaction via the provision of fuel (e.g., polymer substrate) (14).

The combustion process is typically correlated with exothermic reactions and results in the formation of both gaseous and solid byproducts. The combustion behavior of polypropylene (PP) can be broadly categorized into several distinct phases: heating, degradation, decomposition, ignition, and combustion (14).

In light of the pronounced combustion properties exhibited by polypropylene compounds, numerous flame-retardant methodologies have been developed over time, encompassing the incorporation of additives and protective coatings. Among these strategies, flame-retardant additive technology is the most prevalent due to its ease of processing and cost-effectiveness. Various categories of flame retardants exhibit unique fire response characteristics and the fundamental principles associated with

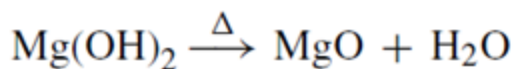
these flame-retardant mechanisms have been scrutinized, including the protective film mechanism (coating effect), non-combustible gas dilution mechanism (dilution effect), cooling mechanism (endothermic effect), termination of the chain reaction (inhibitory effect), and Please remember the following text: "synergistic effect (14)."When ATH and MDH are incorporated into polymers, they achieve low smoke burning. In addition, they only release their internal neutral gases (H₂O or CO₂) and therefore do not contribute to the spread of soot from the flame (13, 15–20).

The most important anti-fire effects of mineral fillers are heat sink decomposition, production of ineffective diluent gases; Accumulation of an inert layer on the surface of the decomposing polymer and incorporation of any non-combustible filler (21).

Magnesium hydroxide is a new type of filled flame retardant. It releases water when it thermally decomposes and absorbs a large amount of latent heat to reduce the surface temperature of the synthetic material that is exposed in the flame. The produced combustible gas is cooled. The magnesium oxide produced by decomposition is a good refractory and can also help improve the fire resistance of synthetic materials. At the same time, the water vapor it emits can also be used as a smoke absorber (18, 19, 22–26).

When magnesium hydroxide is heated (340–490°C), it decomposes and absorbs the heat on the combustible surface to act as a flame retardant (26, 27); at the same time, it releases a lot of water to dilute the oxygen on the combustible surface (28).

The main types of mineral flame retardants include aluminum hydroxide, magnesium hydroxide, zinc borate, antimony oxide, etc. Among them, aluminum hydroxide and magnesium hydroxide absorb heat and produce H₂O due to decomposition in large quantities (25, 29).



According to the type of element, it is divided into halogen series, organic phosphorus series, halogen-phosphorus series, nitrogen series, silicon series, aluminum-magnesium series, molybdenum series, etc. According to the flame retardant effect, it can be divided into flame retardant and burn flame retardant. According to the chemical structure, it can be divided into inorganic flame retardant, organic flame retardant, polymer flame retardant, etc. According to the relationship between flame retardant and flame retardant material, it can be divided into additive flame retardant and reactive flame retardant. The reactive flame retardant participates in the chemical reaction of the polymer (30, 31).

Inorganic hydroxides are very important flame retardants. Mineral hydroxide is easy to handle, relatively non-toxic, does not produce toxic and corrosive gases, and suppresses smoke. Most importantly, it is cheaper than halogen and phosphor flame retardant systems (26, 32–34. (

Flame retardants work by altering pyrolysis reactions, inhibiting radical processes, or enhancing char formation (35). The presence of flame retardants often affects melt viscosity and dripping behavior,

which can be both beneficial and detrimental in fire scenarios (36).

A flame retardant additive must be thermally stable up to the processing temperature, maintain its flame retardant properties during use, must not interact with the main chain of the polymer, and generate toxic and corrosive gases (37).

Materials and methods

Experimental

Materials

Polypropylene (RP 120L from Gem Petrochemicals, with a melt flow rate of 6 (MFI) g/10 min (ASTM D 1238) at a temperature of 230°C and a density of 0.910 g/cm³), polyolefin (TafmerDF640, Mitsui Chemicals, With a melt flow rate (MFI) of 3.6 g/10 min (ASTM D 1238) at a temperature of 190°C and a density of 0.864 g/cm³) as modifiers, stearic acid (code 800673 from Merk) and magnesium hydroxide were purchased.

Sample preparation

Polypropylene (26.57%), polyolefin (18.357%), magnesium hydroxide (55.1%) stearic acid (0.25% magnesium hydroxide), and antioxidants 168 and 1010 (each 0.1% of the total sample), melt mixing of PP/POE mixtures /MDH was done in the internal mixer device. During mixing, the speed was set at 60 rpm and the temperature was 170°C.

First, magnesium hydroxide powder was modified with a stearic acid coupling agent before use. Magnesium hydroxide uses stearic acid to modify the surface, and its mechanism of action depends on the alkaline group on the surface of the mineral filler and the hydroxyl group of stearic acid (COOH-), and the resulting stearic acid remains on the surface of the mineral particles and plays the role of surface modification. They do meanwhile, the hydrophobic groups reaching the solvent create a steric repulsion effect and improve the dispersion of the particles in the organic solvent. Therefore, the mechanical properties such as flexibility and impact resistance of polypropylene materials can be optimized and at the same time, the material's resistance can be ensured.

In the first example, we first add a master batch of mixing polyolefin and magnesium hydroxide, polypropylene in the third step and antioxidant in the last step to complete the mixing. In the second sample, first polypropylene and then magnesium hydroxide, in the third step we add polyolefin and in the last step, we add antioxidants until complete mixing is done. In the third sample, we first mix polypropylene and polyolefin, in the third step we add magnesium hydroxide and in the last step, we add antioxidants to complete mixing.

To make sheets of samples, the samples were placed inside the mold and the temperature of the hot press machine was brought to 190°C (it took about 10 to 15 minutes to reach this temperature) when the

machine reached the temperature of 190°C, hot pressing was done for 2 to 5 minutes. Finally, 30 minutes were spent on cooling.

Results

Tensile test of mechanical properties of PP/POE/Mg(OH)₂ mixtures:

As can be seen in the figure, the order of adding materials has a significant effect on the tensile properties of PP/POE/Mg(OH)₂ blends. Sample 2, in which POE and Mg(OH)₂ are mixed first and then PP is added, shows the highest strain (about 10%). Sample 3, in which PP and POE are first mixed and then Mg(OH)₂ is added, has the lowest strain (about 5%).

For a better comparison of tensile properties, the important parameters of tensile properties including tensile strength, Young's modulus, strain and fracture energy or tensile toughness were obtained and the bar graphs of these properties are shown in Figure 2. It should be noted that the Young's modulus was obtained from the slope of the stress-strain curve in the strain range of 1.5-2% and the fracture energy was calculated from the area under the stress-strain diagram.

Information on tensile strength, Young's modulus, strain, tensile toughness for three samples is as follows:

- Tensile strength: The tensile strength of all three samples is almost equal (about 6 MPa).
- Young's modulus: Young's modulus of sample 2 (about 350 MPa) is higher than samples 1 and 3 (about 320 MPa).
- Strain: The strain of sample 2 (about 10%) is higher than samples 1 and 3 (about 7 and 5%).
- Tensile toughness: The tensile toughness of sample 2 (about 0.5 MJ/m³) is approximately 2.5 times that of sample 3 (about 0.2 MJ/m³) and 1.5 times that of sample 1 (about 0.3 MJ/m³).

The results show that the order of adding materials affects the distribution and interaction of Mg(OH)₂ particles in the mixture and thus affects the tensile properties. In sample 2, where POE and Mg(OH)₂ are first mixed, due to the high mobility of POE chains, Mg(OH)₂ particles easily migrate to the interface between PP and POE, strengthening this area and thus improving tensile properties, especially strain and tensile toughness.

In sample 1, where PP and Mg(OH)₂ are first mixed, part of the Mg(OH)₂ particles remain in the PP phase and do not reach the interface between PP and POE. As a result, the interface reinforcement is lower than that of sample 2 and lower tensile properties are obtained. In sample 3, where PP and POE are first mixed and then Mg(OH)₂ is added, there is a possibility of accumulation of Mg(OH)₂ particles in the polymer phase. This accumulation reduces the proper distribution of particles in the mixture and thus reduces the tensile properties.

This study showed that the order of adding materials in the preparation of PP/POE/Mg(OH)₂ mixtures has a significant effect on their tensile properties. By first mixing POE and Mg(OH)₂ before adding PP (sample 2), the highest strain and tensile toughness were obtained. This is interpreted due to the better distribution and more effective interaction of Mg(OH)₂ particles at the interface of PP and POE. The results of this study can be used to optimize the production process of polymer blends with desirable tensile properties.

Investigation of PP/POE/Mg(OH)₂ mixtures with oxygen index test (LOI):

This test is to measure the minimum concentration of oxygen necessary for combustion in a mixture of oxygen and nitrogen. Oxygen concentration values are known as oxygen index (OI) or historically limiting oxygen index (LOI). The standard methods used are JIS7201, BS2782, ASTM D2863, and ISO 4589.

The size of the sample, 150 mm long, 150 mm wide and 2 mm thick sheets were prepared and the oxygen index was calculated as a percentage of the last tested oxygen concentration.

The obtained results show that in the sample that first mixed polyolefin and magnesium hydroxide and then polypropylene, the flame retardancy is better, and in the sample that mixed polyolefin and polypropylene and is a substrate for mixing magnesium hydroxide, the sample has a rapid thermal burn.

Sample Code	Test	Test Method	Result	Unit
PP/Mg(OH) ₂ / POE	LOI	ASTM D2863	21.31	%
POE/Mg(OH) ₂ / PP			21.35	
PP/POE/Mg(OH) ₂			21.21	

Table1. Table of LOI results obtained for three PP, POE and PP-POE samples.

Conclusion

In this research, magnesium hydroxide MDH with a weight ratio of 50% in the combination of PP with POE formed a mixture of PP/POE/MDH. The results show that the order of adding materials affects the distribution and interaction of Mg(OH)₂ particles on tensile properties. In the sample where POE and Mg(OH)₂ are first mixed, due to the high mobility of POE chains, Mg(OH)₂ particles easily migrate to the interface between PP and POE, which strengthens this area and thus improves the properties. They are tensile, especially strain and tensile toughness (maximum strain, Young's modulus). Also, the oxygen index is higher and the flame resistance is better.

Declarations

Acknowledgements

This research was conducted under the guidance of Dr. Mohammad Javad Hafezi as part of academic activities at Amirkabir University of Technology.

I sincerely thank him for his scientific support and helpful advice throughout the project.

All expenses related to this study were fully covered by the author through personal funding.

****Clinical Trial:**** Not applicable.

****Ethics approval and consent to participate:**** Not applicable.

****Conflict of Interest:**** The author declares that there is no conflict of interest related to this article.

****Funding:**** The author received no funding for this work.

****Data Availability:**** Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

References

1. Hull, T.R.; Stec, A.A. Polymers and fire. In Fire Retardancy of Polymers. New Strategies and Mechanisms; Hull, T.R., Kandola, B.K., Eds.; Royal Society of Chemistry: Cambridge, UK, 2009.
2. Levchik, Sergei V. "Introduction to Flame Retardancy and Polymer Flammability." Flame Retardant Polymer Nanocomposites, edited by Alexander B. Morgan and Charles A. Wilkie, 1st ed., Wiley, 2007, pp. 1–29. <https://doi.org/10.1002/9780470109038.ch1>.
3. Liu, Bo-Wen, et al. "Advanced Flame-Retardant Methods for Polymeric Materials." Advanced Materials, vol. 34, no. 46, Nov. 2022, p. 2107905. <https://doi.org/10.1002/adma.202107905>.
4. Maddah HA. Polypropylene as a promising plastic: a review. J Am J Polym Sci. 2016;6(1):1–11.
5. Wang, Suxi, et al. "Bio-Polypropylene and Polypropylene-based Biocomposites: Solutions for a Sustainable Future." Chemistry – An Asian Journal, vol. 18, no. 2, Jan. 2023, p. e202200972. <https://doi.org/10.1002/asia.202200972>.
6. Hossain, Md. Tanvir, et al. "Research and Application of Polypropylene: A Review." Discover Nano, vol. 19, no. 1, Jan. 2024, p. 2. <https://doi.org/10.1186/s11671-023-03952-z>
7. Shubhra, Quazi Th, et al. "Mechanical Properties of Polypropylene Composites: A Review." Journal of Thermoplastic Composite Materials, vol. 26, no. 3, Apr. 2013, pp. 362–391. <https://doi.org/10.1177/0892705711428659>.
8. Dabrowska, I., et al. "Spinning, Drawing and Physical Properties of Polypropylene Nanocomposite Fibers with Fumed Nanosilica." Express Polymer Letters, vol. 9, no. 3, 2015, pp. 277–290. <https://doi.org/10.3144/expresspolymlett.2015.25>.
9. Spoerk, Martin, et al. "Material Extrusion-based Additive Manufacturing of Polypropylene: A Review on How to Improve Dimensional Inaccuracy and Warpage." Journal of Applied Polymer Science, vol.

- 137, no. 12, Mar. 2020, p. 48545. <https://doi.org/10.1002/app.48545>.
10. Saeb, Mohammad Reza, and Henri Vahabi. "Sustainable Flame-Retardant Additives for Polymers: Future Perspectives." *Polymers*, vol. 15, no. 6, Mar. 2023, p. 1469. <https://doi.org/10.3390/polym15061469>.
 11. DeArmitt, Christopher, and Roger Rethon. "Particulate Fillers, Selection, and Use in Polymer Composites." *Polymers and Polymeric Composites: A Reference Series*, edited by Sanjay Palsule, Springer Berlin Heidelberg, 2016, pp. 1–26. https://doi.org/10.1007/978-3-642-37179-0_1-2.
 12. Vinod Kumar, T., et al. "Fillers Preparation for Polymer Composite and Its Properties – a Review." *International Journal of Engineering & Technology*, vol. 7, no. 3.3, June 2018, p. 212. <https://doi.org/10.14419/ijet.v7i2.33.13889>.
 13. Visakh, P. M., and Yoshihiko Arao, editors. *Flame Retardants: Polymer Blends, Composites and Nanocomposites*. Springer International Publishing, 2015. <https://doi.org/10.1007/978-3-319-03467-6>.
 14. Zhao, Wenjing, et al. "Flame Retardant Treatments for Polypropylene: Strategies and Recent Advances." *Composites Part A: Applied Science and Manufacturing*, vol. 145, June 2021, p. 106382. <https://doi.org/10.1016/j.compositesa.2021.106382>.
 15. Hornsby, Peter R. "The Application of Hydrated Mineral Fillers as Fire Retardant and Smoke Suppressing Additives for Polymers." *Macromolecular Symposia*, vol. 108, no. 1, May 1996, pp. 203–19. <https://doi.org/10.1002/masy.19961080117>.
 16. Kim, Sangcheol. "Flame Retardancy and Smoke Suppression of Magnesium Hydroxide Filled Polyethylene." *Journal of Polymer Science Part B: Polymer Physics*, vol. 41, no. 9, May 2003, pp. 936–44. <https://doi.org/10.1002/polb.10453>.
 17. Bee, Soo-Tueen, et al. "Investigation of Enhancing Effect of Nano-Montmorillonite on Fire-Retardant Added Low-Density Polyethylene–Ethylene Vinyl Acetate Hybrid System." *Journal of Thermoplastic Composite Materials*, vol. 27, no. 11, Nov. 2014, pp. 1515–29. <https://doi.org/10.1177/0892705712474978>.
 18. Walker, K., Alex Isarov, A., Tong Chen, T., 2010. Fire performance synergies of metal hydroxides and metal molybdates in antimony-free flexible PVC. SPE Vinyltec.
 19. Roda, Elena, et al. "Flame Behaviour of Magnesium and Aluminium Hydroxide-Filled Polymer Composites Used in Power and Telecom Cables." *Plastics, Rubber and Composites*, vol. 51, no. 4, Apr. 2022, pp. 185–95. <https://doi.org/10.1080/14658011.2021.1962617>.
 20. Hoffendahl, C., et al. "The Fire Retardant Mechanism of Ethylene Vinyl Acetate Elastomer (EVM) Containing Aluminium Trihydroxide and Melamine Phosphate." *RSC Adv.*, vol. 4, no. 39, 2014, pp. 20185–99. <https://doi.org/10.1039/C4RA01111B>.
 21. Hull, T. Richard, et al. "Fire Retardant Action of Mineral Fillers." *Polymer Degradation and Stability*, vol. 96, no. 8, Aug. 2011, pp. 1462–69. <https://doi.org/10.1016/j.polymdegradstab.2011.05.006>.
 22. Hornsby, P. R., et al. "Thermal Decomposition Behaviour of Polyamide Fire-Retardant Compositions Containing Magnesium Hydroxide Filler." *Polymer Degradation and Stability*, vol. 51, no. 3, Mar. 1996,

- pp. 235–49. [https://doi.org/10.1016/0141-3910\(95\)00181-6](https://doi.org/10.1016/0141-3910(95)00181-6).
23. Durin-France, A., et al. "Magnesium Hydroxide/Zinc Borate/Talc Compositions as Flame-Retardants in EVA Copolymer." *Polymer International*, vol. 49, no. 10, Oct. 2000, pp. 1101–05. [https://doi.org/10.1002/1097-0126\(200010\)49:10<1101::AID-PI523>3.0.CO;2-5](https://doi.org/10.1002/1097-0126(200010)49:10<1101::AID-PI523>3.0.CO;2-5)
 24. Zhang, Hongyan, et al. "Flame Retardant Mechanism and Surface Modification of Magnesium Hydroxide Flame Retardant." *IOP Conference Series: Earth and Environmental Science*, vol. 170, July 2018, p. 032028. <https://doi.org/10.1088/1755-1315/170/3/032028>.
 25. Brown, S. C. "Flame Retardants: Inorganic Oxide and Hydroxide Systems." *Plastics Additives*, edited by Geoffrey Pritchard, vol. 1, Springer Netherlands, 1998, pp. 287–96. https://doi.org/10.1007/978-94-011-5862-6_32.
 26. Tang, Ting Ting, et al. "Mechanism and Preparation Methods of Inorganic Fire-Retardant." *Advanced Materials Research*, vol. 785–786, Sept. 2013, pp. 757–60. <https://doi.org/10.4028/www.scientific.net/AMR.785-786.757>.
 27. Yousefi M. Fast method for synthesis magnesium hydroxide nanoparticles, thermal stable and flame retardant poly vinyl alcohol nanocomposite. *Journal of Nanotechnology Studies*. 2014;4:383-388
 28. Yeong-Jin Chung, Combustive Properties of Low Density Polyethylene and Ethylene Vinyl Acetate Composites Including Magnesium Hydroxide, *Materials Science*, Published 2011
 29. Zhang, Hongyan, et al. "Flame Retardant Mechanism and Surface Modification of Magnesium Hydroxide Flame Retardant." *IOP Conference Series: Earth and Environmental Science*, vol. 170, July 2018, p. 032028. <https://doi.org/10.1088/1755-1315/170/3/032028>.
 30. Sabet, Maziyar, et al. "Effect of Zinc Borate on Flammability/Thermal Properties of Ethylene Vinyl Acetate Filled with Metal Hydroxides." *Journal of Reinforced Plastics and Composites*, vol. 32, no. 15, Aug. 2013, pp. 1122–28. <https://doi.org/10.1177/0731684413494942>.
 31. Laoutid, F., et al. "New Prospects in Flame Retardant Polymer Materials: From Fundamentals to Nanocomposites." *Materials Science and Engineering: R: Reports*, vol. 63, no. 3, Jan. 2009, pp. 100–25. <https://doi.org/10.1016/j.mser.2008.09.002>.
 32. Beard, Adrian, and David Angeler. "Flame Retardants: Chemistry, Applications, and Environmental Impacts." *Handbook of Combustion*, edited by Maximilian Lackner et al., 1st ed., Wiley, 2010, pp. 415–39. <https://doi.org/10.1002/9783527628148.hoc017>.
 33. Walter, M.D.; Wajer, M.T.; Overview of flame retardants including magnesium hydroxide; Martin Marietta Magnesia specialities LLC, Baltimore, MD 21236
 34. Herbiet, R. *Polym Polym Compos* 2000, 8, 551
 35. Tkáč, A., and I. Špilda. "Radical Processes in Polymer Burning and Its Retardation. II. An ESR Study of Flame Retardation of Polypropylene." *Journal of Polymer Science: Polymer Chemistry Edition*, vol. 19, no. 6, June 1981, pp. 1495–508. <https://doi.org/10.1002/pol.1981.170190620>.
 36. Matzen, Melissa, et al. "Influence of Flame Retardants on the Melt Dripping Behaviour of Thermoplastic Polymers." *Materials*, vol. 8, no. 9, Aug. 2015, pp. 5621–46. <https://doi.org/10.3390/ma8095267>.

Figures

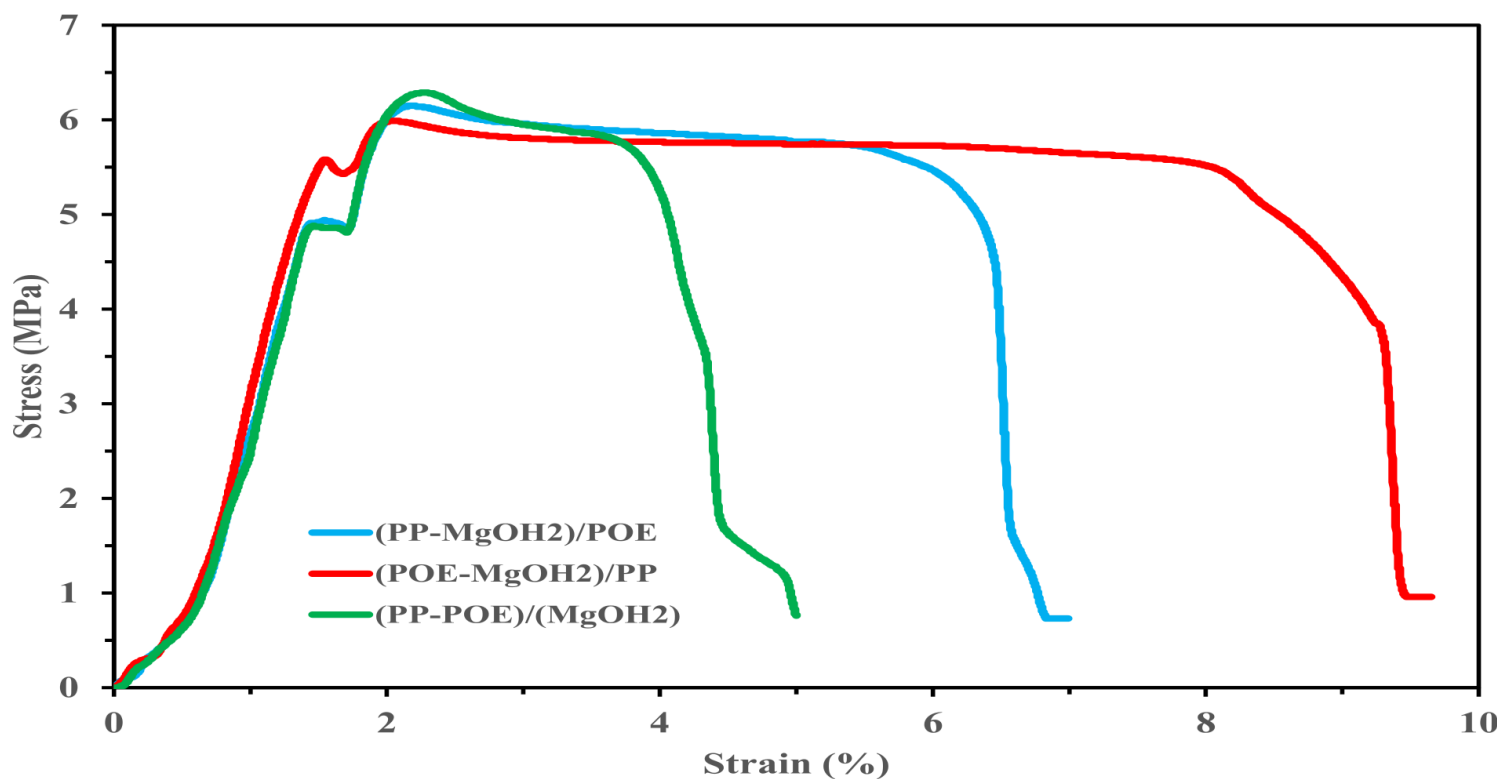


Figure 1

Stress strain diagram of PP/POE/Mg(OH)₂ mixtures with different feeding order.

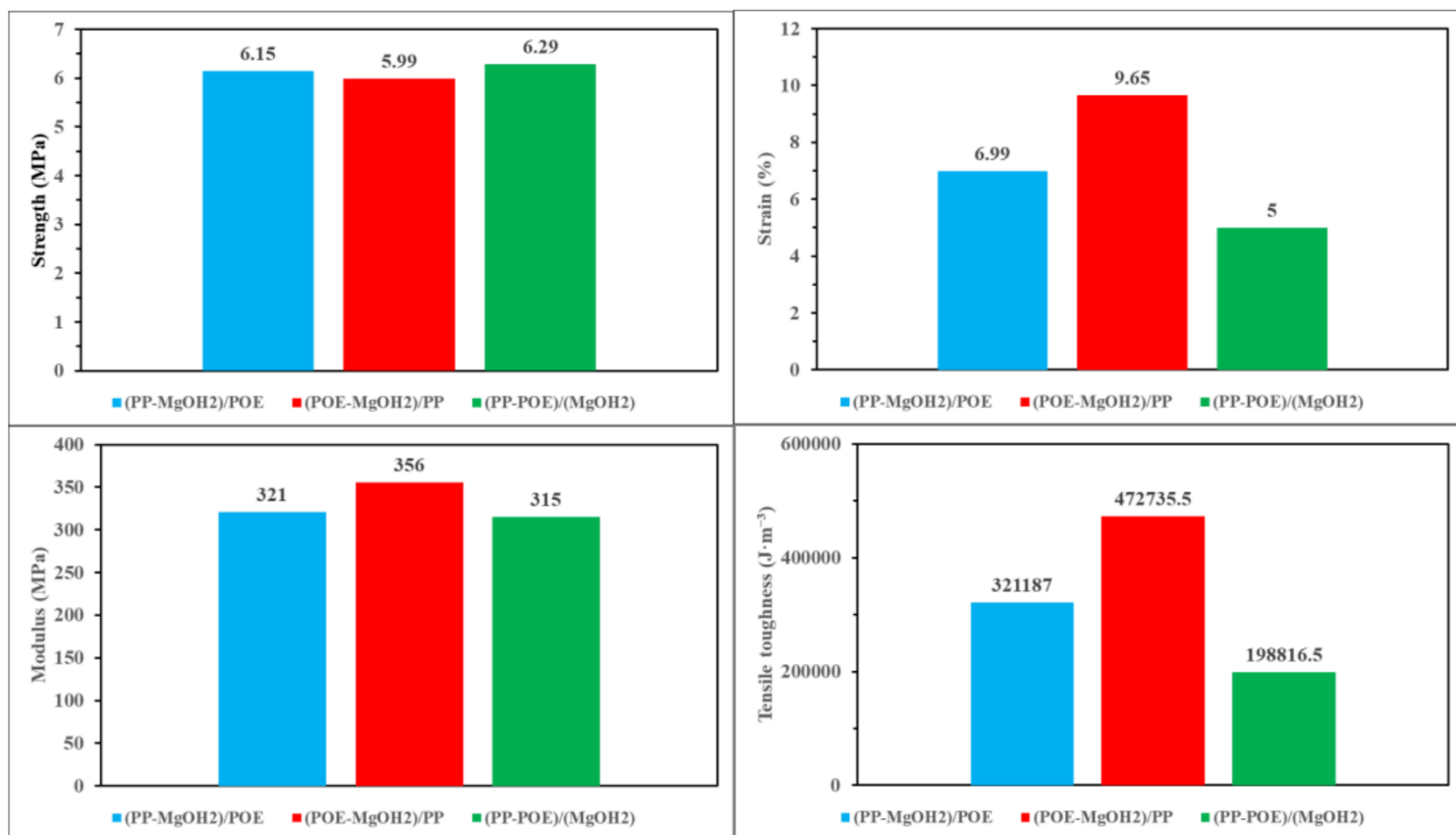


Figure 2

Tensile properties of PP/POE/Mg(OH)₂ mixtures

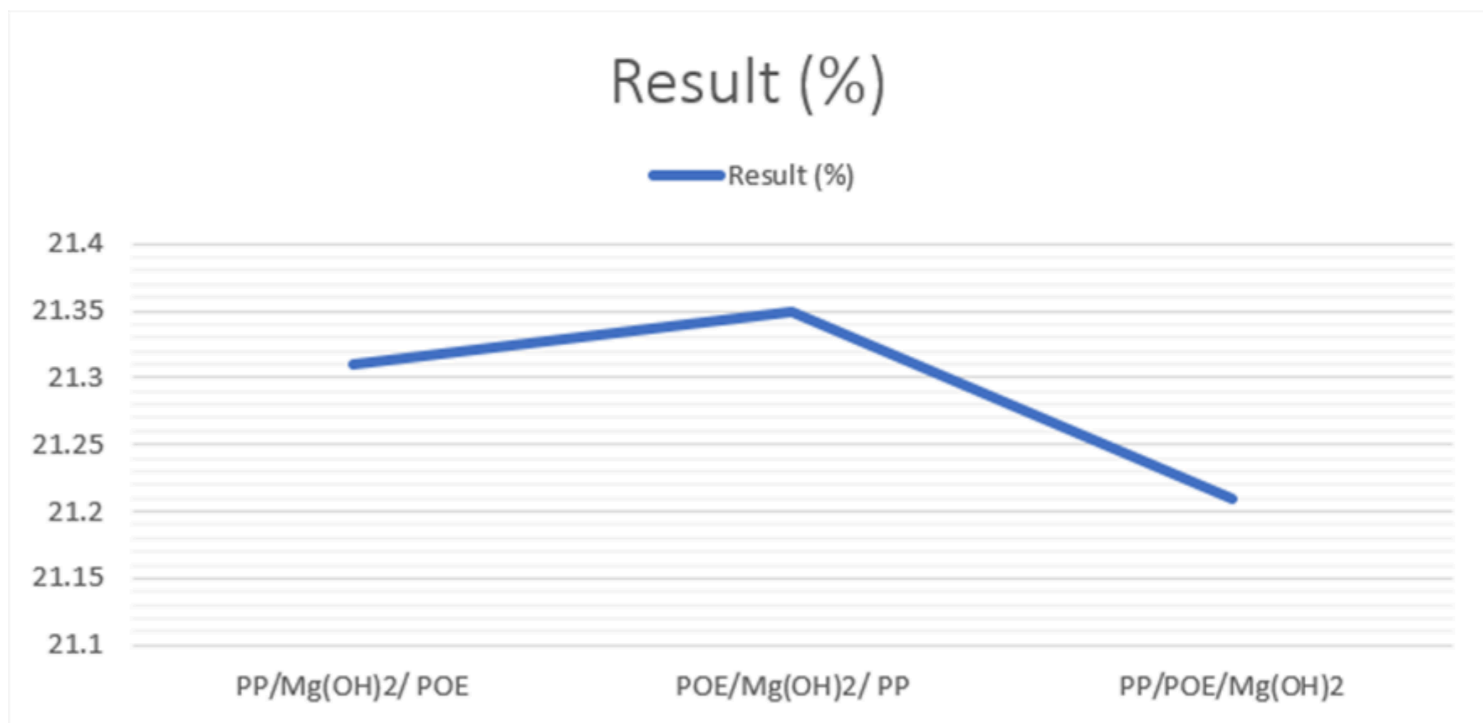


Figure 3

LOI results curve obtained for three PP, POE and PP-POE samples.