Enhancement of Physical Properties of Boehmite/HDPE Nanocomposite Film by Electron Irradiation

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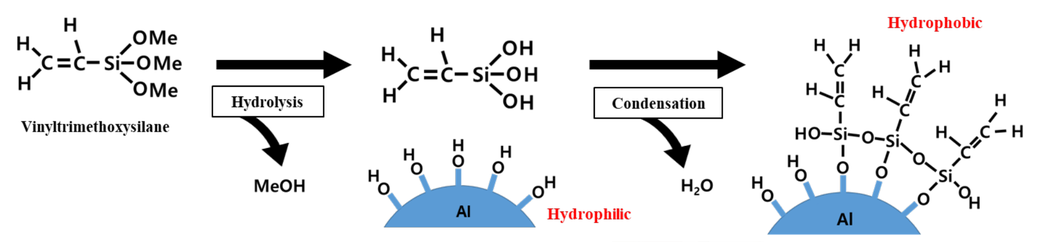
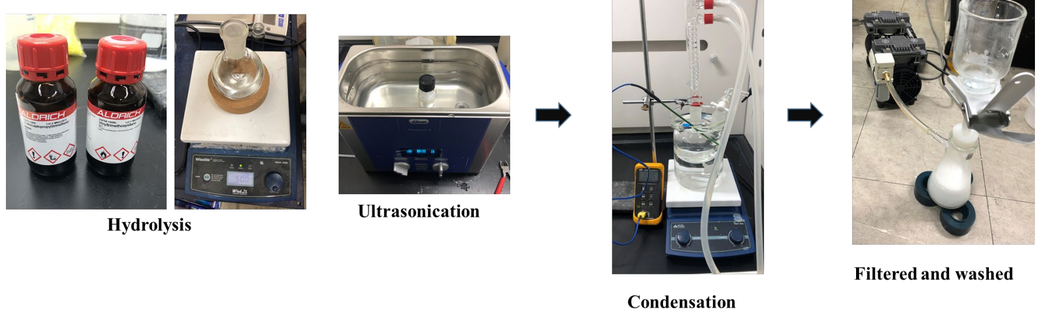
Introduction

- Polyethylene is widely used due to its low cost, high chemical stability, and ease of mass production relative to other polymers. High density polyethylene (HDPE), in particular, has excellent mechanical properties due to its linear nature and high crystallinity.
- The intrinsic properties of HDPE can be enhanced by adding inorganic fillers to form a polymer nanocomposite and used in various industrial fields such as those involving food packaging, power cable, radiation shielding, and battery separator.
- The main issues of fabricating polymer nanocomposites exist in requiring the nano-fillers to adhere well and be thoroughly dispersed within the polymer matrix. Implementation of smaller nanoparticles enhance the properties of polymer nanocomposites more potently; however, the reduction in particle size causes agglomeration to become an even greater problem.
- To address these issues regarding dispersion and interfacial adhesion, the surfaces of the nanoparticles are usually silanized. Silane coupling agents have a polar end that generate covalent bods with hydroxyl groups on nanoparticles, therefore, the silanization process becomes more effective with greater presence of hydroxyl groups.
- Among the possible nanocomposite filler materials, aluminum oxide, or more specifically, boehmite (AlO(OH)), has the highest hydroxyl group content, allowing the material to react readily with silane coupling agents
- However, attempting to utilize thermoplastics with optimal properties, covalent bonds must form between the silane and the thermoplastic matrix. Such covalent bonds can be generated by applying a process such as incorporation of a radiation initiator, however, it produces noxious methane gas.
- An alternative method using electron beam irradiation can accomplish the same goal without the use and the production of harmful chemicals, making the method very attractive. When polyethylene is irradiated with electrons, crosslinking occurs, and thus, physical properties of the polymer can be enhanced.
- In this study, a silanized boehmite/HDPE nanocomposite film was irradiated with electrons to enhance the interfacial adhesion between the nanofiller and the HDPE matrix. By enhancing the interfacial adhesion, a significant improvement in the mechanical and the thermal properties of the nanocomposite film was able to be achieved.

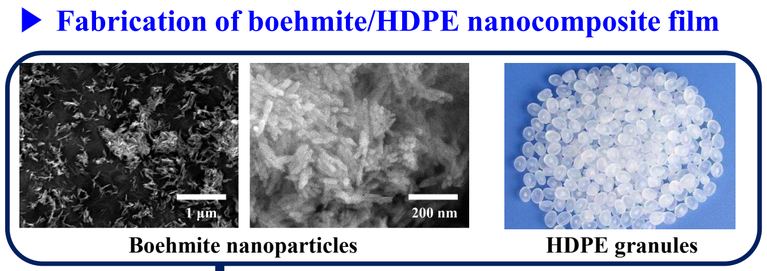
Methods

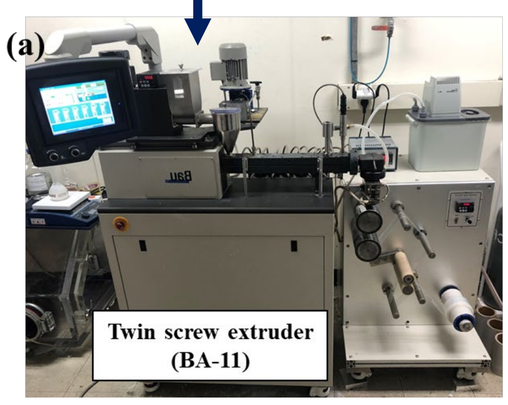
Surface treatment of boehmite nanoparticles

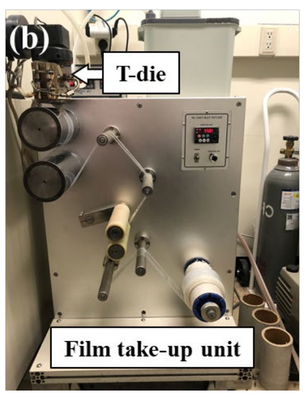




Fabrication of boehmite/HDPE nanocomposite film



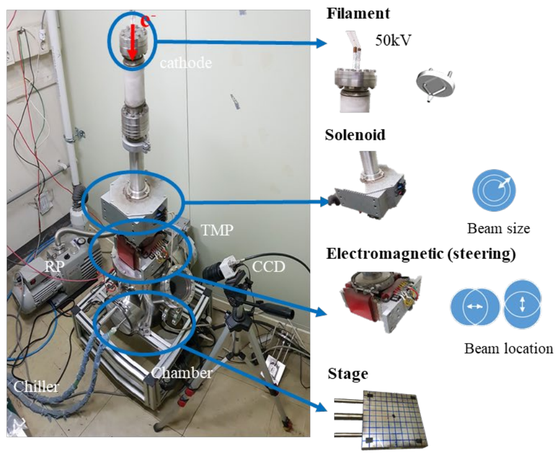


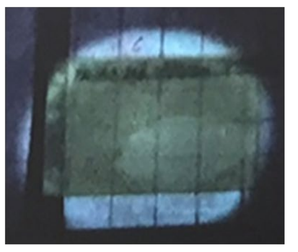


Optimization of fabrication conditions

Fabricated nanocomposite films

Electron irradiation





Electron Energy	50 keV
Current Density	< 1.5 × 10^{14} /cm^2
Degree of Vacuum	< 5 x 10^{-5} Torr
Beam Diameter	60 mm

Characterization

Morphology

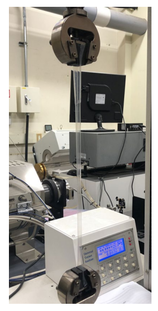
Fractured in liquid nitrogen

Scanning Electron Microscope (SEM)
SU5000

Chemical Reaction

Fourier Transform Infrared Spectroscopy (FTIR)
Nicolet iS50

Mechanical Strength

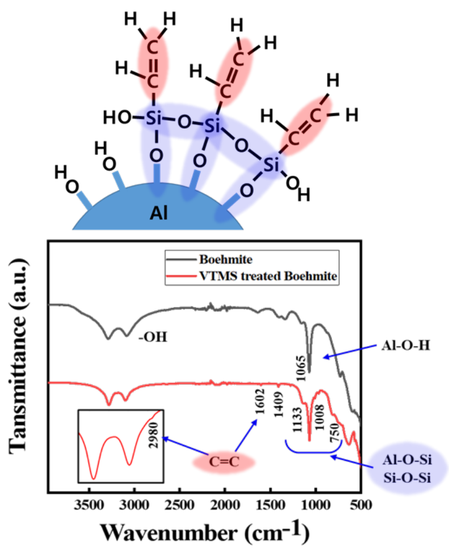


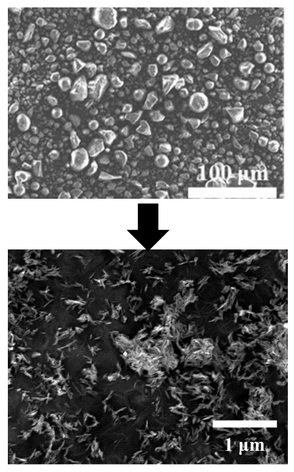
- ASTM D882-18
- Load cell = 5 kN
- Gauge length = 40 mm
- Crosshead speed = 50 mm/min

Universal Testing Machine (UTM)
Yeonjin S-Tech

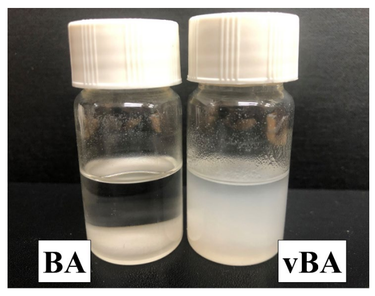
Results

Surface treatment of boehmite nanoparticles



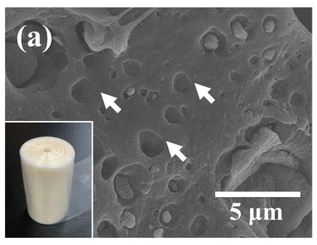


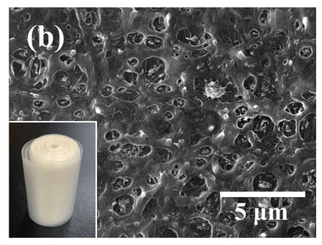
Boehmite before and after surface treatment



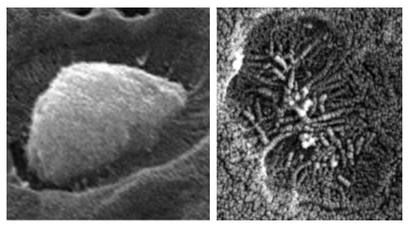
Dispersed in toluene for 3 days
➔ Better dispersion in organic solvent
➔ Less agglomeration

Cross-section of nanocomposite films



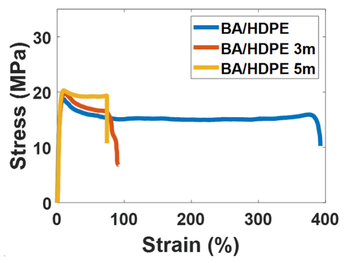


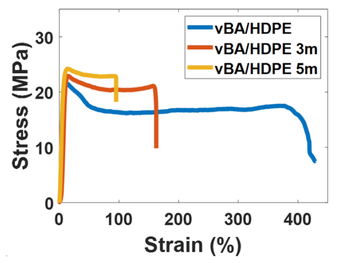
Better dispersion by silane treatment



Enhanced interfacial adhesion by EB

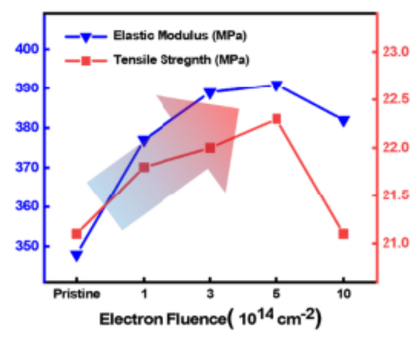
Tensile tests





BA = boehmite
vBA = VTMS treated boehmite

vBA / HDPE



Conclusion

- HDPE, boehmite/HDPE, and surface treated boehmite/HDPE films were prepared by melt blending were irradiated with electrons under vacuum.
- The surface-modified nanofiller showed superior dispersion in HDPE compared to the unmodified nanofiller. Electron irradiation causes vBA nanoparticles to form strong co-valent bonds with the HDPE matrix by radical grafting.
- The applicability of the approach introduced in this work is not limited to HDPE and vBA; by carefully considering physical properties, it can be applied to other materials to achieve similar results.