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Physicochemical and mechanical properties of polypropylene-cellulose nanocrystal nanocomposites: effects of manufacturing process and chemical grafting

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Introduction

Chemical modifications have been widely adopted for improving the dispersibility of cellulose nanocrystals(CNCs) in nonpolar matrixes. The current study was conducted to find an appropriate functionalization technique for CNCs and an effective manufacturing process for CNC-polypropylene(PP) nanocomposites. The surface structures of CNCs were successfully changed using toluene diisocyanate(TDI) and maleic anhydride grafted PP(MAPP). The tensile properties and thermal stability of the nanocomposites with MAPP grafted CNCs were higher than those of pristine and TDI grafted CNC systems.

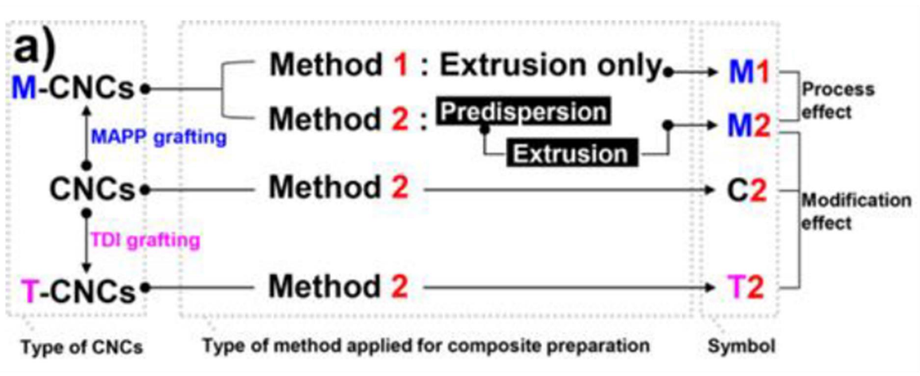
Experimental

Materials

- Cellulose(W-50, KC Flock, Japan) was used as a source of CNCs
  - particle size : < 45 um, bulk density : 0.15 g/ml~0.2 g/ml
- Isolation of the CNCs : hydrolysis using 64 wt% H_2SO_4

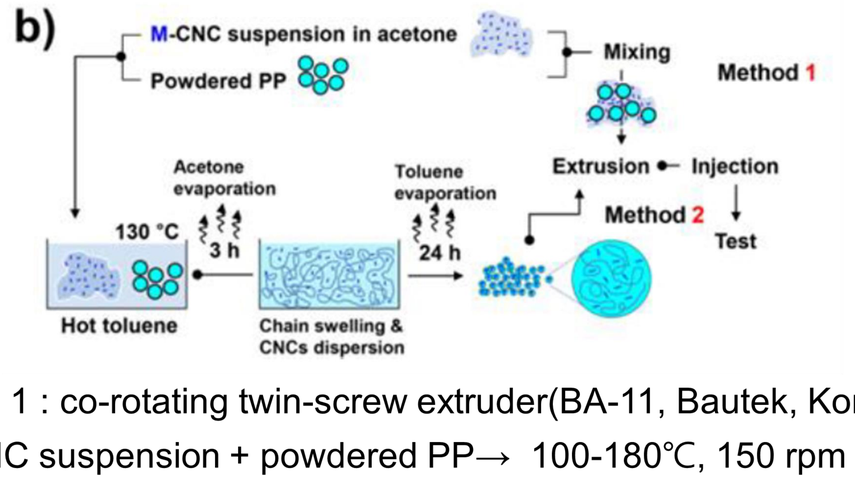
Methods

Surface grafting of CNCs with TDI, MAPP



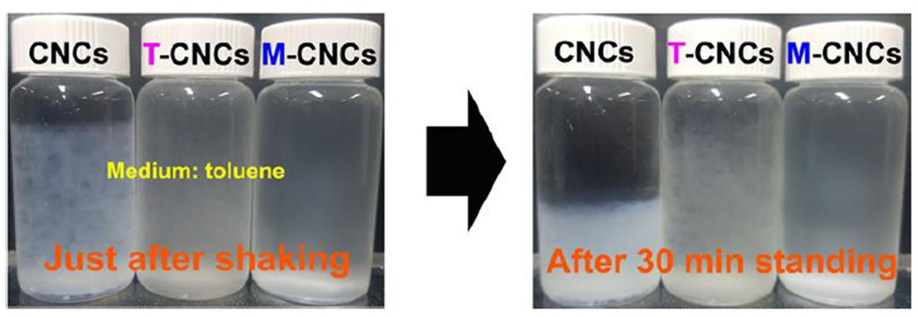
- TDI modification(T-CNCs) :
  - Solvent-exchanging(DMF) → add TDI at 70℃, 24 h
  (2:1 equivalents ratio of isocyanate group in TDI to hydroxyl group in CNCs)
- MAPP modification(M-CNCs) :
  - CNCs + toluene + MAPP at 130℃, 1 h

Preparation of nanocomposites

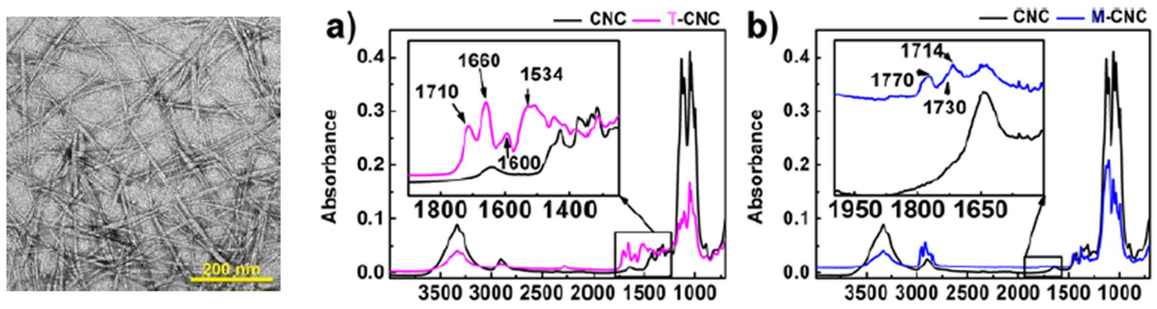


- Method 1 : co-rotating twin-screw extruder(BA-11, Bautek, Korea)
  - M-CNC suspension + powdered PP→ 100-180℃, 150 rpm
- Method 2 : polymer dilute system
  - M-CNCs + toluene + PP(solid : liquid = 1 : 100) at N_2 atmosphere, 3 h
  (after evaporation of toluene, the obtained powder was extruded in Mehtod 1)

Results and Discussion

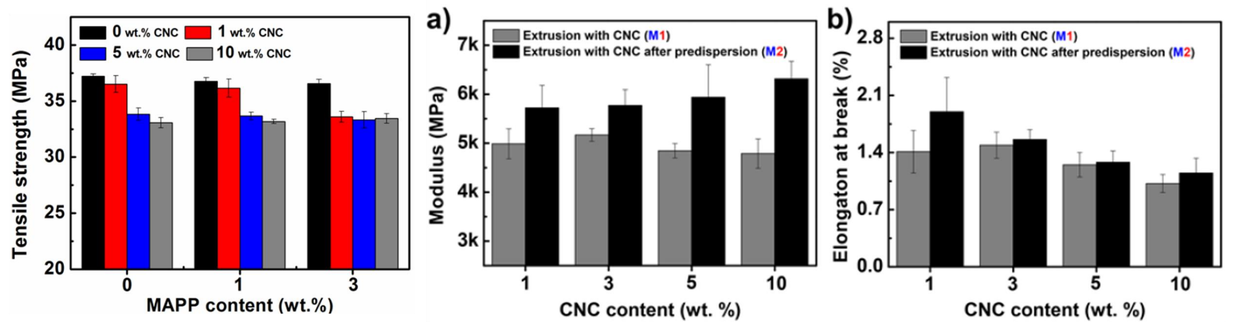


<Differences in the dispersion level among pristine, T-CNCs and M-CNCs in toluene>

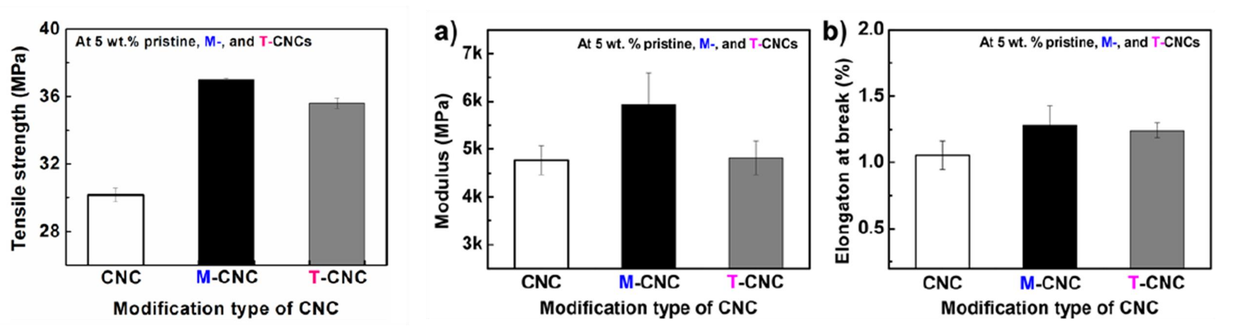


<TEM image & FT0IR spectra of the cellulose nanocrystals>

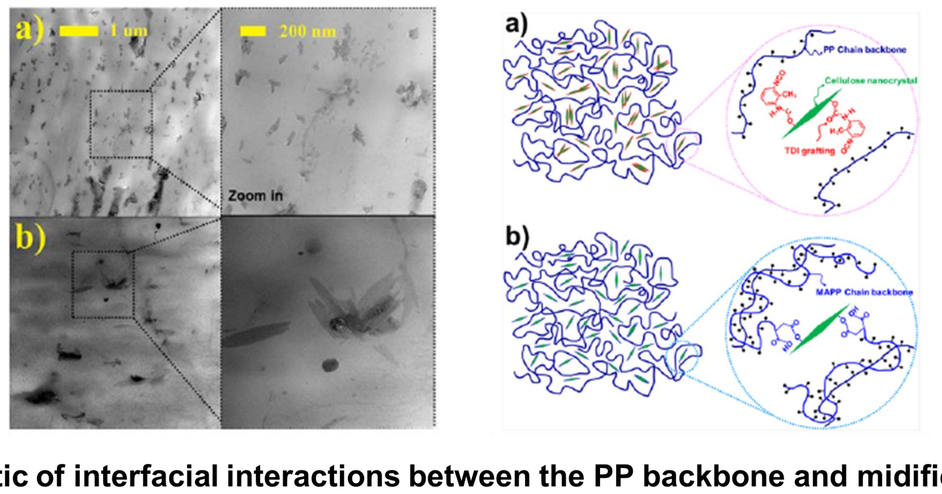
- Length & width : 154 nm(±23 nm), 5.8 nm(±1.3 nm)
- FT-IR(a) : carbonyl peak(1710, 1574 cm^{-1}) resulted from isocynate(-NOC)
  1600 , 1660 corresponding to C=C(toluene), C-N(amide(NHCO))
- FT-IR(b) : 1714, 1730, 1770 cm^{-1} indicate the reaction between maleic anhydride and hydroxyl group from CNCs



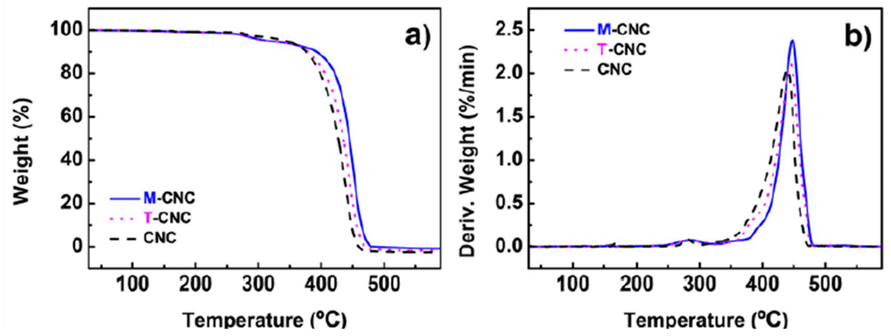
<Tensile strength of CNCs-PP composites and effect of the predispersion step>



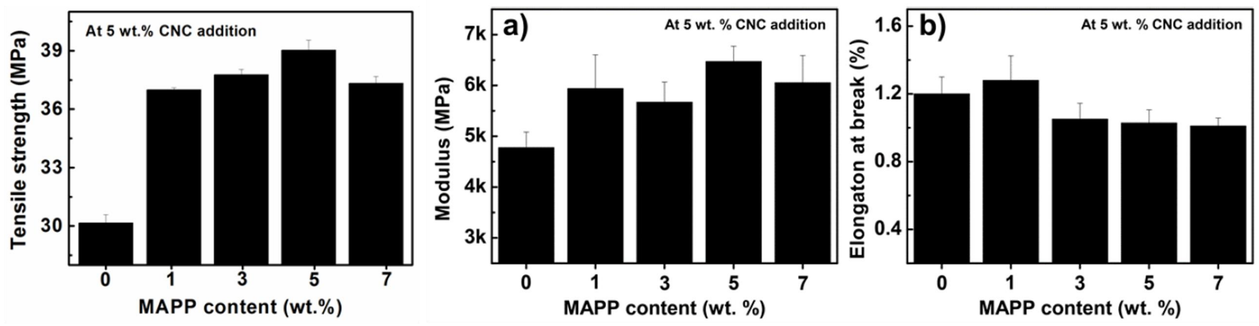
<Mechanical properties of CNCs-PP nanocomposites using chemical modified CNCs>



<Schematic of interfacial interactions between the PP backbone and midified CNCs>



<TGA results of PP-CNCs nanocomposites>



<Mechanical properties of PP-CNCs nanocomposites with the MAPP contents>