# Development of functionalized wood composites for smart products

Guan Gong[1*], Birgitha Nyström[1], Runar Långström[1], Rathish Rajan[2], Egidija Rainosalo[2], Zainab Al-Maqdasi[3], Roberts Joffe[1,3]

[1] *Swerea SICOMP AB, Box 271, SE 941 26, Piteå, Sweden.*
[2] *Centria University of Applied Sciences, Kokkola, Finland 67100*
[3] *Luleå University of Technology, SE 971 87, Luleå, Sweden.*
*Corresponding author (guan.gong@swerea.se)

**Keywords**: *Wood plastic composite; graphene; extrusion; multifunctionalities*

## Introduction

Wood plastic composites (WPCs) are frequently used in wood-like applications such as decking and sidings. Wood flour is available in large quantities in countries with abundant forest resources and developed forestry industry (e.g. Scandinavia). It is a side stream from sawmills produced when timber is refined. It is an underutilised renewable resource which is perfect for WPC production. However, WPC doesn't seem to be the material of choice for decking and sidings in the Scandinavian countries since people prefer natural wood. Therefore, an Interreg North project "Smart WPC" (2017-2019) was initiated to develop WPC materials for high-end "smart" applications. The materials would in this case compete with for example plastics from fossil resources. Novel and smart bio-based materials are expected to attract consumers and especially the ones with growing environmental awareness.

This study aims at bridging knowledge and technology gaps so that functionalized bio-based WPC products may become a material for the fossil-free future society. The objective is to evaluate the graphene nanoparticles (GNPs) for means of functionalisation. GNP has outstanding mechanical properties and electrical & thermal conductivity (1). Well dispersed and exfoliated in a polymer, GNP can improve properties of the matrix significantly properties (2). Thus obtained nanocomposite can serve as the matrix in functionalized WPC.

The materials should have properties suitable for applications such as thermal conductivity for anti-icing/de-icing board or EMI shielding for housings of electronic components. The thermal conductivity at room temperature of known bulk materials used in electronics applications range from 0.2 W/(m·K) for polymethylmethacrylate (PMMA) to 3.4 kW/(m·K) for isotopically purified diamonds. EMI shielding efficiency of materials should be above 20 dB for commercial applications. Addition of GNPs to polymer and later to WPC is expected to influence the thermal and electrical as well as mechanical properties in both cases. Several factors, among which the morphology is the most critical, will influence whether the functionalised WPCs can be classified as thermally conductive or/and EMI shielding materials. There can be three morphological states of GNPs dispersed in polymers and WPCs - phase separation, intercalation and exfoliation. When good dispersion and sufficient exfoliation is achieved, property improvements should be obtained at low GNP loadings. When distance between nanoplatelets is short enough the percolation threshold for electrical and thermal properties can be reached. It is known from the literature that the electrical percolation threshold requires close proximity between platelets for particle tunnelling, approximately 5 nm (2). If the thermal one is similar, remains to be evaluated. On the other hand, immiscibility of phases and/or insufficient exfoliation of GNPs can result in large agglomerates; marginal improvement or even decrease of properties can be expected in that case.

The current work first presents the manufacture of GNP modified nanocomposite with the polymer to be used as the matrix in WPC. The bigger challenge will most likely be in the second step; the influence of GNPs in combination with bio-based fibres and coupling agent on mechanical, thermal and electrical properties of the hybrid composite structures (WPC). The outcome of the study will indicate whether functionalized WPCs can in fact become an interesting material for the targeted applications.

## Experimental

A high density polyethylene (HDPE, MG9647S from Borealis), and two GNP/ HDPE master batches of with a GNP content of 25% (GB) and 35% (heXo-G V20) by weight (from Nanoxplore) were used to prepare nanocomposites and functionalized WPCs. A maleic anhydride grafted polyethylene (MAPE, E265 from Du Pont) based on an HDPE with melt flow rate close to that of the HDPE matrix, was used as compatibilizer in WPC. The HDPE, two masterbatches and MAPE are all in pellet form. Both nanocomposites and (functionalized) WPC were processed by means of melt compounding in a Krupp Werner and Pfleiderer co-rotating twin screw extruder.

Three different GNP loadings, 2, 6 and 15 weight-%, were used in the nanocomposites. In WPC the loadings of wood flour varied as 25 and 40 weight-%; the weight ratio between MAPE and wood flour was fixed as 1.5/40; the GNP content was 15 weight-% based on the total weight of WPC and on polymer, respectively.

The structures of both nanocomposites and WPCs were studied in SEM microscope. The mechanical properties were obtained by means of tensile and three-point bending tests. Conductivity of nanocomposites with different GNP contents as well as that of the produced WPCs was measured.

## Results

Preliminary results from SEM microscopy show that GNPs are distributed uniformly throughout the polymer although large particles or agglomerates are occasionally seen, as shown in Fig. 1 (left). Mechanical test results show that addition of GNP significantly increases flexural and tensile (properties of HDPE, tensile properties can beas seen in Fig. 1 (right). Stiffness and yield strength of GNP/HDPE nanocomposites increases almost linearly with increasing GNP loadings without the aid of additional coupling agent, and scatter is small. This may indicate good adhesion by mechanical interlocking between GNPs and HDPE matrix.

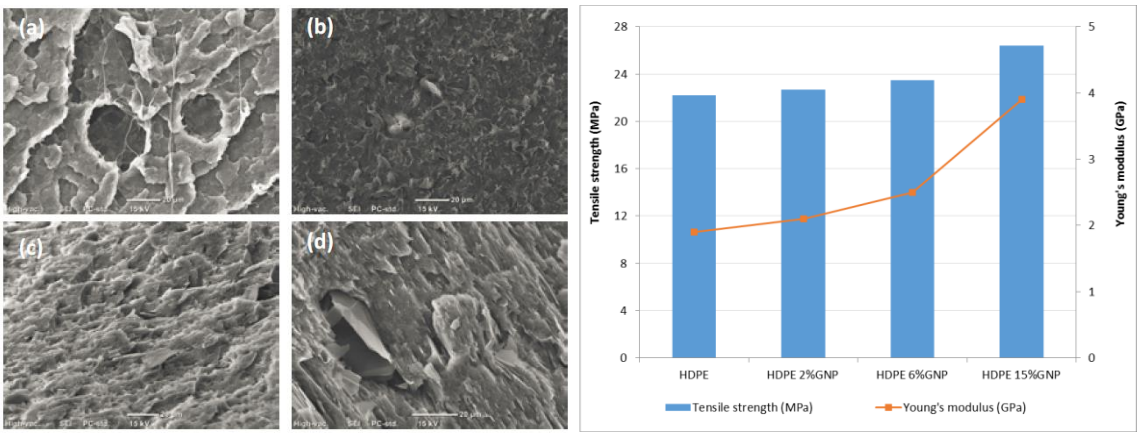


**Figure 1:** *SEM images (left) of PE doped with GP (a – PE, b – 2wt% GP, c – 6wt% GP, d – 15wt% GP). Stiffness and yield stress from tensile test (right) of neat HDPE and HDPE with different GP content*

The conductivity measurements of nanocomposites and WPCs as well as mechanical performance of WPCs will show weather thresholds for electrical and thermal conductivity are reached as well as good reinforcing effect of GNPs in WPC, which we aim to test soon.

## Acknowledgements

This study was financially supported by Interreg Nord project "Smart WPC" (funded by EU and Region Norrbotten). Authors would like to thank EEIGM student Astrid Lecouturier (project student within T7009T course at LTU) for help with experiments.

## References

[1] G. Gong, Literature study of graphene modified polymeric composites, SIO Grafen, https://siografen.se/app/uploads/2018/02/Literature-study-of-Graphene-modified-polymeric-composites.pdf

[2] Lee C, Wei X, Kysar JW, Hone J. Measurement of the elastic properties and intrinsic strength of monolayer graphene. Science 2008, 321, 385-8.