Proceedings of the Symposium on Safety Issues and Regulatory Challenges of Nanomaterials (NanoLCA2012), 3-4 May 2012, San Sebastián, Spain. ISBN:978-92-79-28071-9

Safety assessment of novel polymer-silicon composites - from LCA perspective

Huijun Zhu[1]*, Adeel Irfan[1], Sophia Sachse[2] and James Njuguna[2]
1. Cranfield Health, 2. Centre for Automotive Technology, Cranfield University, UK
*** Correspondence author: h.zhu@cranfield.ac.uk**

Introduction

The fast growing trend in the development of novel materials with potential applications in many industrial sectors has caused concerns over the environment and human health effect of the emerging activities and associated products. It is imperative that these concerns are addressed in a holistic manner as early as possible. As part of the NEPHH project, this study applied the LCA concept aiming to identify hazardous nanoparticles (NP) that could be released during the development and application of novel products, focusing on polymeric-silicon composites in recognition of their attractions to a wide range of industries, including construct engineering, automotive and aerospace [1].

Methods

The specimens of two groups of polymeric-silicon composites, each comprising polyamide 6 (PA6) or polypropylene (PP) as a matrix reinforced with silica nanofiller (Aerosil 200, hydrophilic; Aerosil 974, hydrophobic; both with average size 12 nm) or microfillers (montmorrillonite, glass fiber or foam glass crystal), were fabricated. Neat PA6 and PP polymers were used as references. The generation of airborne NP from the specimens under drilling, a typical scenario of product application, was monitored using a scanning mobility particle sizer in a test chamber. The dust NP recovered via filtration were characterized using scanning electron microscopy (SEM) and dynamic light scattering (DLS). For in vitro toxicity assessment of NP, Human lung epithelia A549 cells were used. The toxicity was assessed by generation of oxidative stress, inflammatory mediator (interleukin 8), and loss of cell membrane integrity. Silica NP 7 nm (Si7) and H2O2 (200 µM) were used as positive controls.

Results and Discussion

It was shown that under drilling process, the PA6 group specimens generated more air borne NP than the PP group with the polymeric-silica nanocomposites generating the most. These airborne NP formed aggregates when reaching concentration of 500000 NP/cm^3 or higher, depending on the type of specimens, and subsequently settled down in the dust (Figure 1).

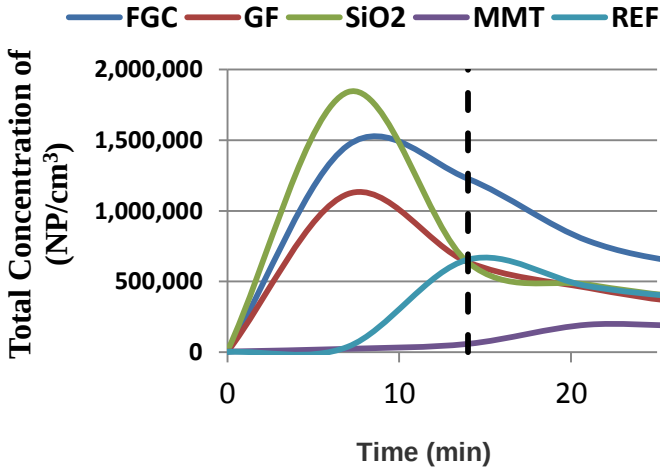

Figure1. Monitoring of air borne NP generated during drilling of PA6 group of specimens. The lines represent NP released from PA6 reinforced with silica NP (SiO2), microfiller of montmorillonite (MMT), foam glass crystal (FGC), and glass fiber (GF). PA6 polymer was used as a reference (REF).

The formation of aggregates in the air was also confirmed by SEM examination (data not shown). When dispersed in the culture medium at concentrations of 25-100 µg/ml, the hydrodynamic size of all the dust NP was within nanoscale as measured by LDS (data not shown). All the dust NP exhibited no

or low toxicity potency (Figure 2 A and B). In comparison, raw silica NP (SiNP 7 nm and Aerosil 200) showed stronger toxicity as indicated by the induction of acute effects on cell membrane integrity (Figure 2 C compared with A and B), generation of oxidative stress and IL-8 (data not shown). The Aerosil 974 showed no effect on cell membrane integrity, which could be due to the hydrophobicity.

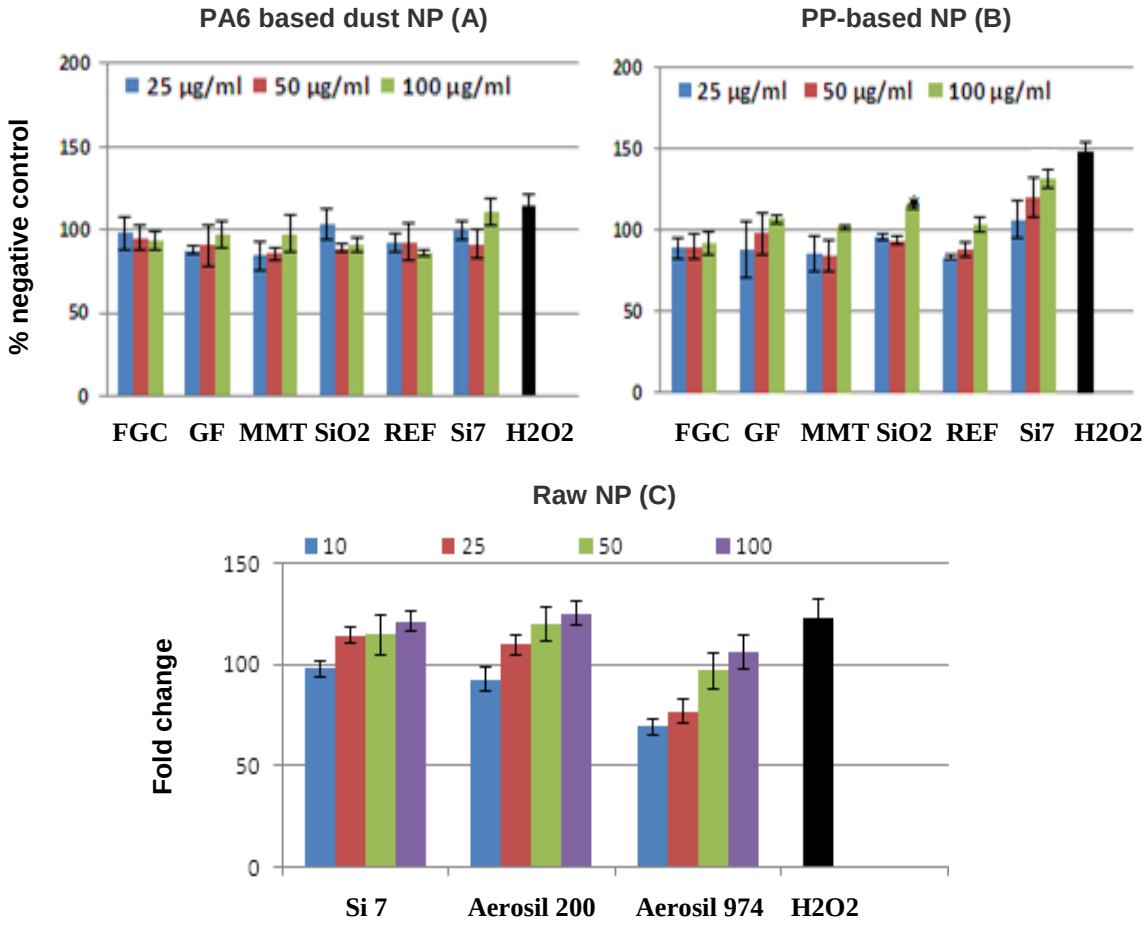

Figure 2. Assessment of cytotoxicity of dust and raw NP in human lung epithelia A549 cells. The cytotoxicity was assessed by the cellular membrane integrity (LDH) assay. Bars in A and B represent effect of NP released from polymers reinforced with nanofiller silica NP (SiO2), microfiller montmorillonite (MMT), foam glass crystal (FGC), and glass fiber (GF). The bars in C represent the effect of raw silica NP.

This study demonstrated the differences in the level of NP release between PA6 and PP-based polymeric composites and toxicity potency between the polymer-based NP and the raw silica NP, suggesting that LCA of the release and toxicity of NP could result in more reliable outcomes informing safety evaluation of novel products. Further studies are needed to assess the safety of novel products under scenarios representing all life stages from raw materials sourcing to final product disposal and recycle**.**

Acknowledgement. This research was financially supported by the European Commission's 7th Framework programme under the project NEPHH (Grant number: CP-FP 228536-2). We wish to thank Professor Krzyszt Pielichowski at the Department of Chemistry and Technology of Polymers, Cracow University of Technology, Krakow, Poland, for supplying all the investigated polymer materials.

References

[1] Hua Zou, Shishan Wu and Jian Shen, Chem. Rev. (2008), 108, 3893–3957.