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Published in:
Proceedings of the NOSA Symposium 2014

2014

Link to publication

Citation for published version (APA):

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Characterization and emission measurements of fibrous aerosol nanoparticles during production of nanotubes and nanowires

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Keywords: Carbon nanotubes, nanowires, emission measurement, SEM

\section*{Introduction}
Nanotechnology has brought with it a new era in material science with new materials being discovered in a rapid phase. The transition from conventional materials has driven the research to explore new allotropes of classic materials including new aerosol based production techniques. Two types of the materials undergoing extensive research are carbon nanotubes (CNTs) and semiconductor nanowires (NWs). These materials show vastly different potential applications but share a common feature; they have significant fibre characteristics and can be emitted as an airborne particle during manufacturing and handling. We present measurements and efforts to characterize these novel materials from an occupational perspective.

\section*{Methods}
We have conducted aerosol emission and exposure measurements during production of Multi-walled CNTs and NWs. The two companies producing the material are both in a transition from research production to industrial production and so the methods they use for maintenance and handling of the material would still be relevant when the processes are up-scaled. Filter samples were collected during different stages in the production to identify possible release of airborne particles. A suite of online aerosol instrumentation ranging from miniaturized personal monitors to sophisticated size spectrometers were also used in order to get time-resolved data and assess the validity of the filter samples. The filter samples were analysed using scanning electron microscopy.

\section*{Conclusions}
The two measurement campaigns showed that there was release of fibrous nanomaterials in both cases. However, the level of release was vastly different. An effort was made to classify the particles released during CNT production and typical particles are shown in Fig. 1. The release of CNTs was during specific work tasks above the internationally proposed occupational limit of 0.01 fibres/cm\textsuperscript{3}. In the case of NW no exposure was detected in the workers breathing zone, but NWs were released in the emission zone (Fig. 2). The measurements showed that there is a need for risk management strategy to increase the workers safety when new methods of production are scaled-up to industrial applications. The measurements shows that in order to measure release of fibrous nanoparticles the measurement strategies needs to be adapted and the picture of the released particles becomes much more complex if one wants to measure and identify the fibrous fraction. We recommend using off-line electron microscopy for detection of fibrous NP emissions. However, there is a strong need to develop on-line techniques specific for fibrous particles.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig1.png}
\caption{CNT particle types (1-4) released during production. The white scale bar equals 1 µm in each image.}
\end{figure}

Figure 1. CNT particle types (1-4) released during production. The white scale bar equals 1 µm in each image.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig2.png}
\caption{Nanowire particle released during maintenance.}
\end{figure}

Acknowledgements
This work was performed within the FAS centre METALUND and supported by the Swedish Council for Working Life and Social Research (FAS) and nmC@Lund