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Laser Fumes of fs Laser Processes – Product, Process and Environment Considerations

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Abstract

Laser treatment is increasingly used in material patterning. Avoiding thermal impact is for some of them crucial to achieve high quality products. This requirement led to recent increased utilization of ultra-fast laser processes. The following article investigates laser safety requirements of ultra-fast processes with respect to particle generation, shape and filtration. Especially, particles of ultra-fast processes are significantly smaller and have a non-hemispherical shape, which asks for specialized solutions to achieve a long filter lifetime.

Ablation, Ultra Fast Lasers, Process Control, filtration

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1. Introduction

Advanced laser processes are increasingly utilized in production. The latter fosters an in depth understanding of laser fumes, which are a major factor of product quality, machine life and environmental/safety & health considerations. Short pulse laser processes are focused on non-melting preparations. On this bases exciting new applications arise. Starting from hard-glas manufacturing, over thin film photovoltaic patterning to Lithium Ion Battery electrode structuring virtually every advanced technology relies on ultra-short pulse laser processes. [1-6]

2. Experiment

The presented study was performed on a femto second laser with a wavelength of 1064nm [3]. Correlations between type of ablated material, particle size distribution as well as particle concentration have been investigated. Especially, the difference in particle size between steel and plastic has been evaluated.

Material processing was captured close to the source and sucked towards a filter was determined continuously using an Engine Exhaust Particle Sizer in the range from 5.6 to 560 nm. For this purpose a sample was taken within the sample are positively charged and move within an electric field towards electrometers where their charge is transferred. The charge is a measure of particle-surface-are particles reach different electrometers. Based on current flows particle size distributions are calculated. In addition sample where taken from the filter and investigated by Secondary Electron Microscopy (SEM) for analyzing the shape of the particles.

Figure 1: Exhaust- and filtersystem LAS260 for ultra fast plaser processes
The raw gas was filtered using the filter-system „LAS260“, a storage filter with F9 pleat pre-filtration. This pre filter consists of high surface area with a well-defined cross flow to ensure long filter life. A secondary particle filter with the HEPA class H14 ensured cleaning capability to 0,005% of total particle count. Further down the gas stream activated carbon was located to remove eventual reminders of hazardous gases from the laser process.

Additionally, the performance of the filter system “LAS260” was determined. For this the laser was kept in stationary conditions and the particle concentrations in raw gas and purified gas were measured using the EEPS-method.

3. Results and Discussion

Fig.2: Particles of steel from a fs-ablation process (resolution scale: 1µm)

Fig.3: Particles of steel from a fs-ablation process (resolution scale: 200nm)
Based on these findings filter technology has to be revised. Starting from extraction, the high kinetic energy of these particles has to be taken into account. Small particles are faster due to kinetic impact. The basic rule of extracting the fumes close to the source needs to be extended to another extraction point further up for capturing the small particles in the nm-range as well.

As the size of these particles is mainly in the range of nm, they can enter the lung-blood barrier, causing high risks on health. Therefore standard filter technique is in many cases not suitable for air cleaning.

Figure 6 depicts the basic principle of particle filtration as used in LAS260. As demonstrated the majority of the particles are kept in the F9 filter, ensuring low maintenance cost for the operator.

Figure 7 depicts the measurement results of EEPS during the plastic process. The statistic maximum of plastic particles was at $d=90\text{nm}$ with a concentration of $3.4 \times 10^5$ particles per cubic centimetre. This value is well above acceptable concentrations for high product quality and operator health. By employing the filter sandwich of LAS60 the clean gas was on the same level as the background signal of the lab with $dN<10^2$ #/cm$^3$. Hence a high quality operation in terms of laser fume is possible.
4. Summary

Ultra fast laser processes, especially in the femto second range have been investigated in terms of particle distribution during the operation. Particle size is found to be in the range of \(d=50\text{nm}...200\text{nm}\) in significantly high concentrations of up to \(10^6 \text{#/cm}^3\). By using the new LAS260 with pleat filtration and HEPA post filtration a fractional deposition is the filter of \(\gg99\%\) was demonstrated. For non-cancerous and mutagenic materials the filtered air can be re-circulated in the working environment for saving energy cost.

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References