PlasTEP

plasma for environment protection

# Field test at Yacht Service Sp. z o.o. in Tanowo/ Poland

M. Schmidt, R. Brandenburg, A. Schwock

## Executive Summary

A field test was performed in order to investigate the feasibility of the treatment of process air containing styrene by the means of plasma based technology. The plasma source and the power supply were successfully installed and operated to treat the process air emitted during the production of hulls. The sensitive diagnostical equipment was operated inside a van. Styrene was decomposed almost completely under all experimental conditions.

## Introduction

The company Yacht Service Sp. z o.o. Tanowo is located near Szczecin in the North-Western part of Poland and produces different hulls and formed components out of polyester, vinyl- and polyester resin[1]. During the production, styrene contaminated air is generated. The removal of this bad smeling compound by means of plasma- based technology was the aim of this field test.

## Experimental setup

The experimental setup used is depicted schematically in Figure 1. The process gas was sucked by a pump out of the production site through the plasma source. The plasma source was energized by a high-voltage power source provided by the project partner Technical University Szczecin. The electrical data (voltage, current, frequency, power) were measured and analyzed by a digital oscilloscope via voltage and current probes. A part of the process gas was directed to an FTIR-spectrometer (**f**ourier **t**ransform **i**nfra**r**ed) and an FID (**f**lame **i**onization **d**etector) to be analyzed. The data recorded during this analysis were recorded real-time on a mobile computer.

Part-financed by the European Union ( European Regional Development Fund )

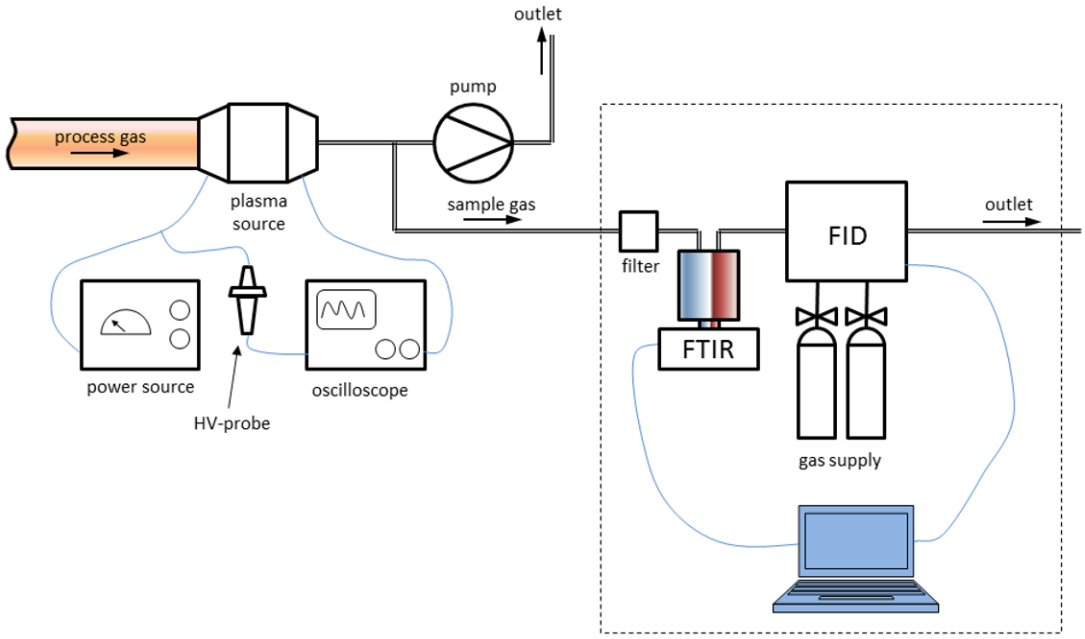


Figure 1: Experimental setup

This analytical part of the experimental setup (marked by the dashed box in Figure 1) was operated in a van (Mercedes Vito, see Figure 2), whereas the plasma source and the plasma was placed outside the (Figure 2).

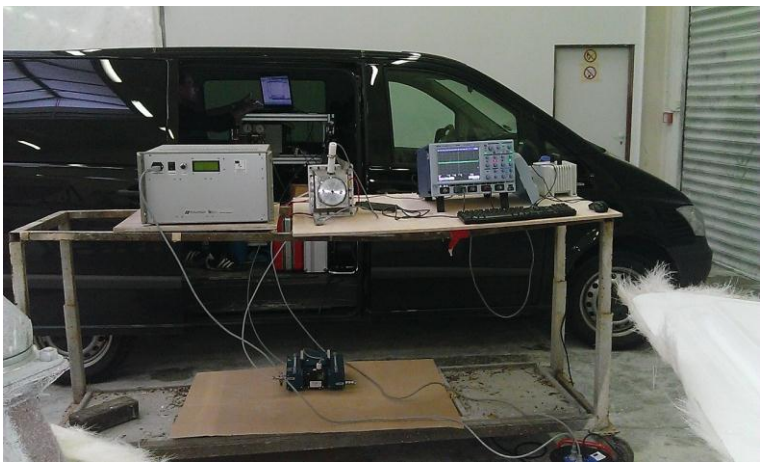

Figure 2: Photograph of the experimental setup (under construction), front: plasma source, power supply and electrical diagnostics, back: van with sensitive gas diagnostic equipment (FTIR-spectrometer and FID)

## Results – FID-measurements

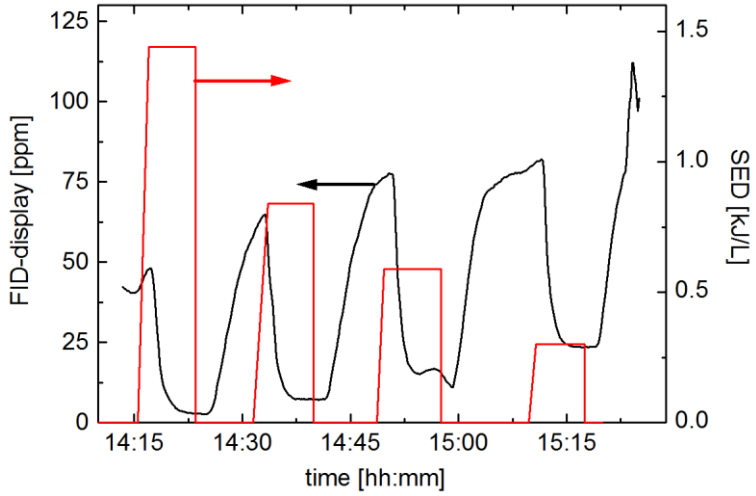


Figure 3: FID-display and SED with respect to time

The plasma treated process air was analyzed by means of FTIR and FID. The data measured by the FID, which counts the number of hydrocarbon-bonded carbon atoms, are displayed in Figure 3 (black curve). The red curve shows the **s**pecific **e**nergy **d**ensity (SED). The SED is calculated by division of the power dissipated into the plasma and the corresponding gas flow. The graphs show that after switching on the plasma, indicated by the increase of the SED, the concentration of **v**olatile **o**rganic **c**ompounds (VOC´s) decreases significantly reaching a minimum value after about five minutes. After switching off the plasma the concentration of VOC´s increases again. Thus, the feasibility of the removal of VOC´s from a process air by means of plasma technology is shown.

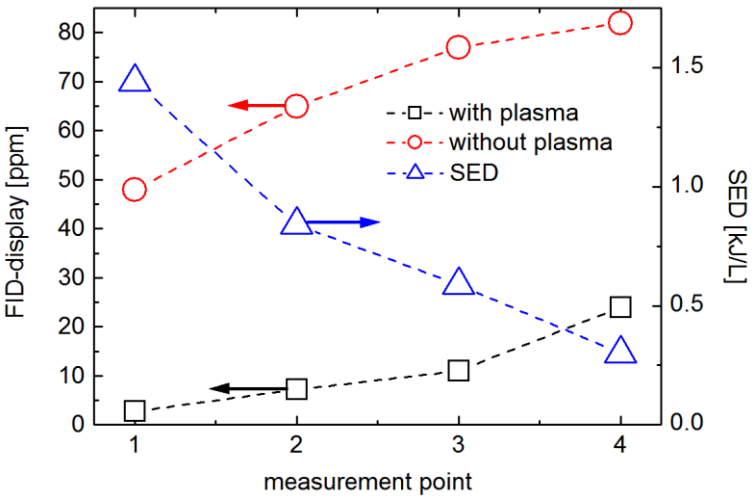


Figure 4: Results of the FID-measurements of the plasma treatment of of the process air

As can be found in Figure 3 the VOC-concentration before switching on the plasma changes as well as the VOC-concentration during the plasma treatment. These variations are due to the changes in the production process and in the operating settings for the plasma source, which were done in order to get as much information as possible during this field test experiment. The different values are summarized in Figure 4. As can be concluded from this figure the amount of VOC´s is removed almost completely at the highest SED applied. Even at the lowest SED applied a significant part of the VOC´s is removed by the plasma process (see Table 1).

## Results – FTIR-measurements

Because the FID gives only information of the concentration of VOC´s in general, for the investigation of other species and single VOC-species an FTIR-spectrometer was used.

As mentioned by Yacht Service Sp. z o.o., the contamination of the process air with styrene is an important issue. Therefore, the concentrations of styrene were analyzed quantitatively during the experiments. The results are shown in Figure 5. In the beginning of the experiments (measurement point 1) the contamination of the process air with styrene was in the range of 6 ppm, which was reduced during the plasma on-phase to around 3 ppm. Due to changes in the production process the concentration of styrene increased during the experiments to around 18 ppm which was also decreased to values below 3 ppm in the plasma on-phase , although the applied SED was reduced from 1.44 kJ/L to 0.3 kJ/L. Because of this result it is assumed that even lower values of applied energy could be sufficient to remove styrene almost completely from the process air.

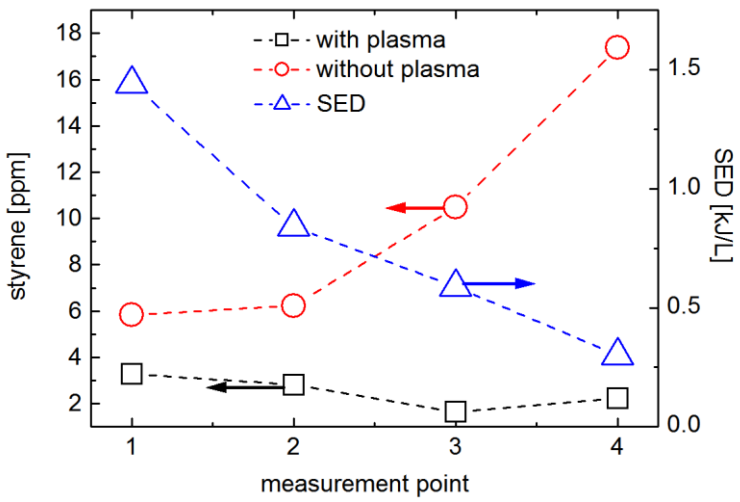


Figure 5: Concentrations of styrene with and without plasma and the corresponding SED applied to the process

## Results – additional spectral information

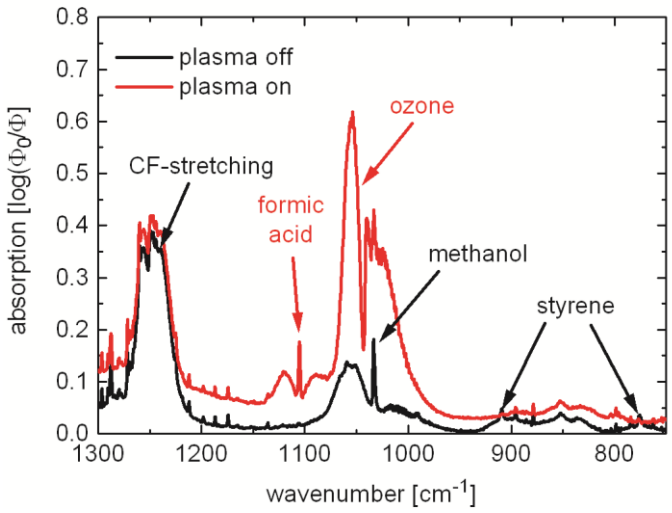


Figure 6: Samples of the infrared spectra of the process air during plasma off phase (black curve) and plasma on phase (red curve)

Additional to VOC´s and styrene various compounds were found by investigation of the infrared spectra of the process air during plasma off and plasma on condition. An example of this analysis is displayed in Figure 6. The black curve corresponds with the absorption during the plasma off phase, which means that the air is untreated, whereas the red curve depicts the result of the plasma treatment during the plasma on phase. The untreated process air contains additional to styrene also methanol. Furthermore, the presence of a carbon-fluorine-containing compound is indicated by the appearance of the CF-stretching absorption band. The sample of the infrared spectrum of the treated gas mixture shows significant ozone absorption bands which were expected because ozone is the main long-living component produced by a plasma operated under ambient conditions. Moreover, the spectrum shows the disappearance of the styrene absorption bands due to the removal of styrene by the plasma treatment. This is accompanied by the appearance of absorption bands of formic acid, which is a major product of the reaction of styrene with ozone[2]. Again, the carbon-fluorine-containing compound can be found. The analysis of all infrared spectra delivered that this absorption band is always to be found and unaffected by the plasma treatment.

## Summary and outlook

During this field test the plasma system and the sensitive analytical equipment were successfully installed and operated. The amount of total VOC´s in the process air was analyzed with an FID which revealed a significant removal of VOC´s by plasma treatment. Styrene as the most important pollutant was identified by FTIR spectroscopy. The removal of styrene by means of plasma technology was shown, too. The results are summarized in Table 1. The increase in removal efficiency

of styrene with decreasing SED is an artefact of the measurements, because styrene was almost totally removed with all power settings but the inlet concentration was increasing during the experiments by a factor of 3. The total VOC concentration was increasing by a factor of 1.5 from 50 to 80 ppm accompanied with an almost constant removal of about 60 ppm. This results in a decreasing removal efficiency.

| SED [J/L] | VOC-removal [%] | styrene removal [%] |
|---|---|---|
| 1440 | 94 | 44 |
| 840 | 89 | 55 |
| 588 | 86 | 84 |
| 300 | 71 | 87 |

Table 1: Summarized results, for further information please see the text

It is found that the process air additional to styrene also contains methanol and a carbon-flourine containing component. As a product of the removal process of styrene formic acid was identified. Unlike styrene formic acid is soluble in water which leads to the suggestion that combining the plasma system with a scrubber could remove the pollutant from the process air. This should be further investigated. Moreover, additional investigations are useful to get information about the minimum energy density needed to get reliable statements about the economic efficiency of the plasma process.

## References

[1] Internet presence of the company Yacht Service Sp. z o.o.: http://www.yachtservice.com.pl/my-de.html
[2] Tuazon E.C., Arey J., Atkinson R., Aschmann S.M., Gas-Phase Reactions of 2-Vinylpyridine and Styrene with O and $NO_3$ Radicals and $O_3$, Environ. Sci. Technol., Vol. 27, No. 9, 1993