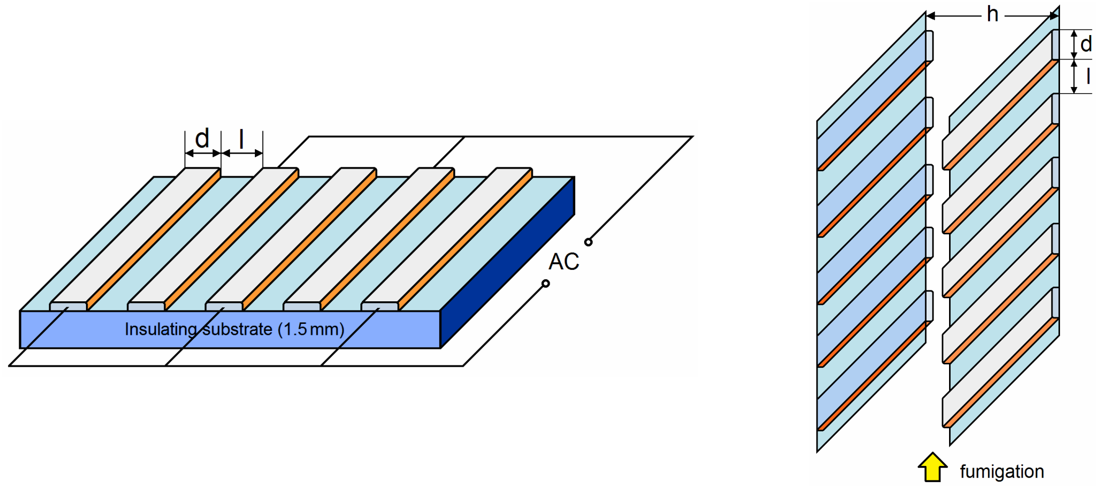
Experimental device and results

The next step of our research activity will focus on the validation of the proposed model. Some preliminary but promising experimental results were obtained.

A detail of DEP-based separation device with parallel interdigitated bar electrodes placed on the bottom surface is illustrated in figure 1a), and the outline of the laboratory experimental device in figure 1b).



a) b)

Figure 1: Detail of DEP-based separation device with parallel interdigitated bar electrodes placed on the insulating substrate, a), schematic representation of experimental device used for DEP separation, placed in work position, b).

Based on results obtained from simulations, was designed was realized the microfluidic experimental device with interdigitated bar electrodes for retaining of nanometric particles from combustion gases in non-uniform electric fields (under dielectrophoresis). The active parts of the microfluidic separation device are identically, the scheme of a part is shown in figure 2, where l=d=100µm.

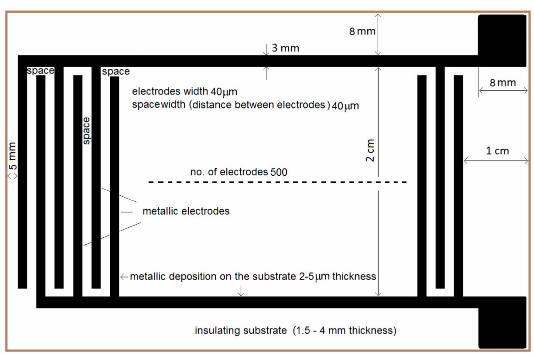
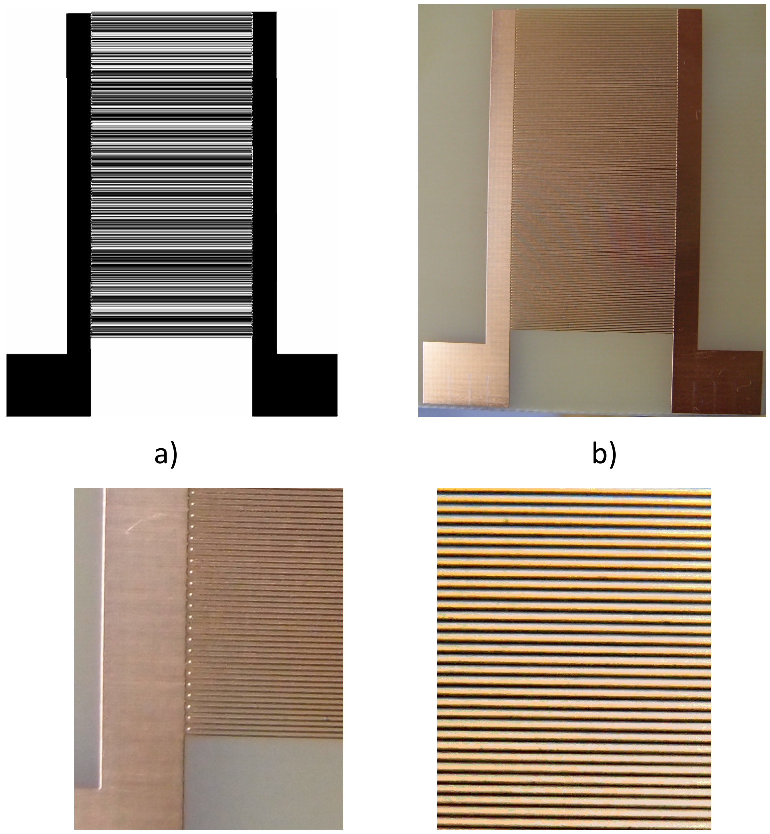


Figure 2: The scheme o a deposition plate, as part of the DEP-based microfluidic separation device.

The Gerber diagram (the layout made at micrometric scale), necessary for the accomplishment of a part of the experimental device is presented in figure 3a), and a deposition plate realized by PCB technique (patterned printed circuit board, followed by gold coating of the copper layer, on insulating plate), at the University of Offenburg Germany, in figure 3b).

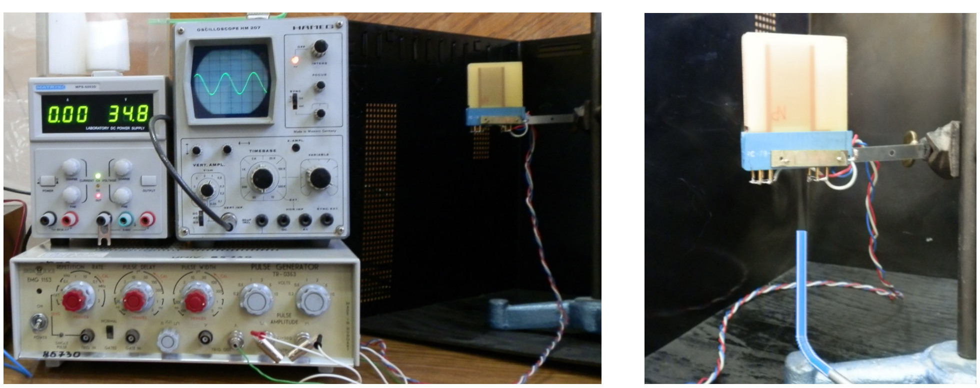


a) b)

c) d)

Figure 3: Gerber diagram representing the layout at micrometric scale, a), the deposition plate of microfluidic experimental device with interdigitated electrodes realized by PCB technique (patterned printed circuit board, followed by gold coating of the copper layer, on insulating plate) b), detail of the interdigitated bar electrodes, c) and zoomed image (10x) of the electrodes, d).

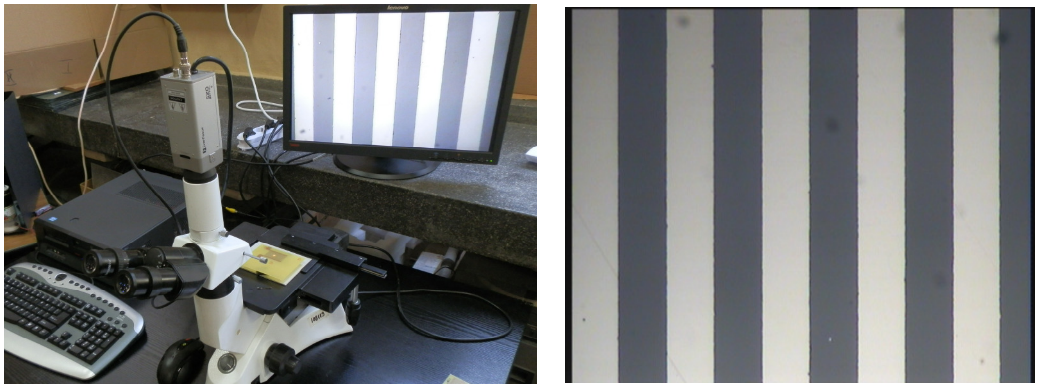
From a practical viewpoint, we performed experiments for nanoparticle trapping from flue gas, by fumigations at the bottom of the experimental device. The installation is presented in figure 4a), and a detail with experimental device in work (with flue gas fumigation at the bottom), in figure 4b).



a) b)

Figure 4: The experimental installation, a), device at work with flue gas at the bottom, b).

Figure 5a) presents the installation for the analysis of the deposition plates (consisting in a reflection metallographic microscope with CCD camera and the related computer), during analyze of a deposition plate before fumigation, in the absence of the applied voltage. Figure 5b) represents a snapshot of a detail of the deposition plate obtained at 100x. The vertical light stripes on the display are the electrodes, while the dark stripes are the gaps.



a) b)

Figure 5: the installation for the analysis of the deposition plates, a), a snapshot of a detail of the deposition plate obtained at 100x, b).

The tests performed with a DEP-based separation device having l=d=100µm and h=2mm reveal that in the absence of the applied voltage the particles are not at all attracted to the electrodes, while once applied an AC voltage dielectrophoretic effect appears. Figure 6 presents successive snapshots after fumigation (U=12V, AC, 50Hz, time of fumigation t=30s), and figure 7 presents successive snapshots after fumigation (U=37V, AC sinusoidal signal, f=50Hz, time of fumigation t=30s), highlighting the deposition of nanoparticles on electrodes (light stripes) from the bottom to the top of the device. More than that, the concentration of captured particles clearly diminishes while we depart from the input region, which is in concordance with our previous simulations.

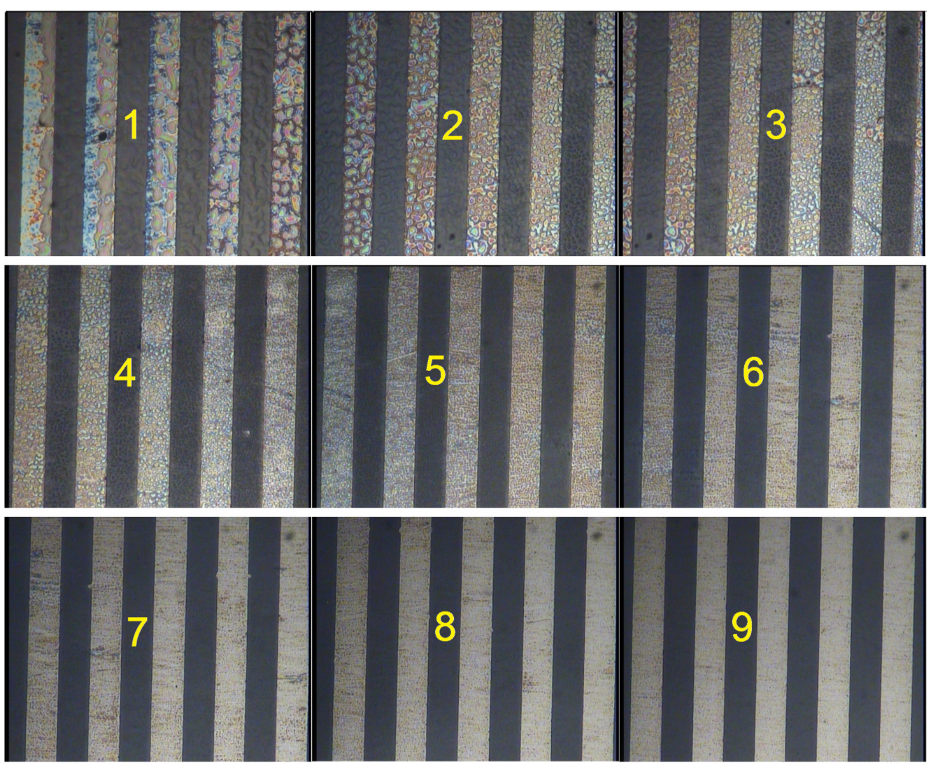


Figure 6: Successive snapshots revealing the results obtained after fumigation with the DEP-based separation device: l=d=100µm, U=12V, AC sinusoidal signal, f=50Hz, time of fumigation t=30s.

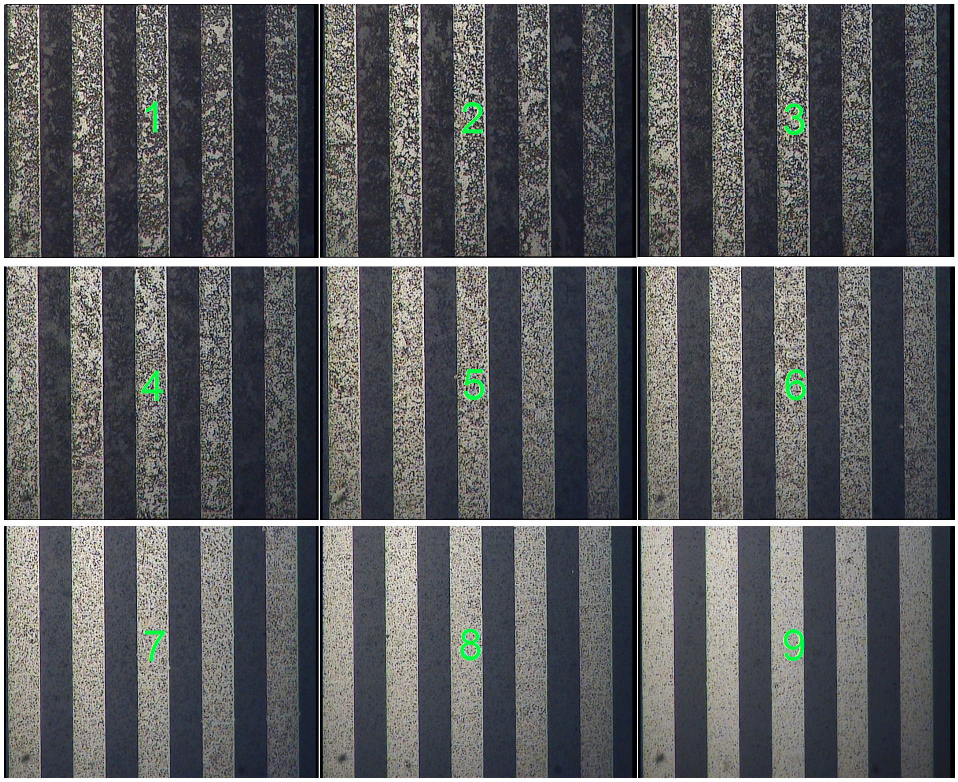


Figure 7: Successive snapshots revealing the results obtained after fumigation with the DEP-based separation device: l=d=100µm, U=37V, AC sinusoidal signal, f=50Hz, time of fumigation t=30s.

After this qualitative validation, we will proceed to a quantitative evaluation of the concentration of nanoparticles captured at the electrodes, at different distances from the input of the device, necessary to give a solid validation of the model.

CONCLUSIONS

This contribution presents an experimental study of a DEP-based microsystem for the selective manipulation of nanoparticles using dielectrophoresis. The DEP force depends on the gradient of the energy density, which changes on the length scale of the electrodes and is a short-range effect. It can be modulated by changing the frequency and electrical properties of the suspending medium. We applied a theoretical model and build-up of an experimental device for retaining the nanoparticles from combustion gases in non-uniform electric fields based on the simulations of a physically realistic problem, and then performed experiments on nanoparticle trapping from flue gases. The experiments highlight the deposition of nanoparticles on electrodes and the fact that the concentration of captured particles clearly diminishes while we depart from the input region, in concordance with our previous simulations.

Comparative results

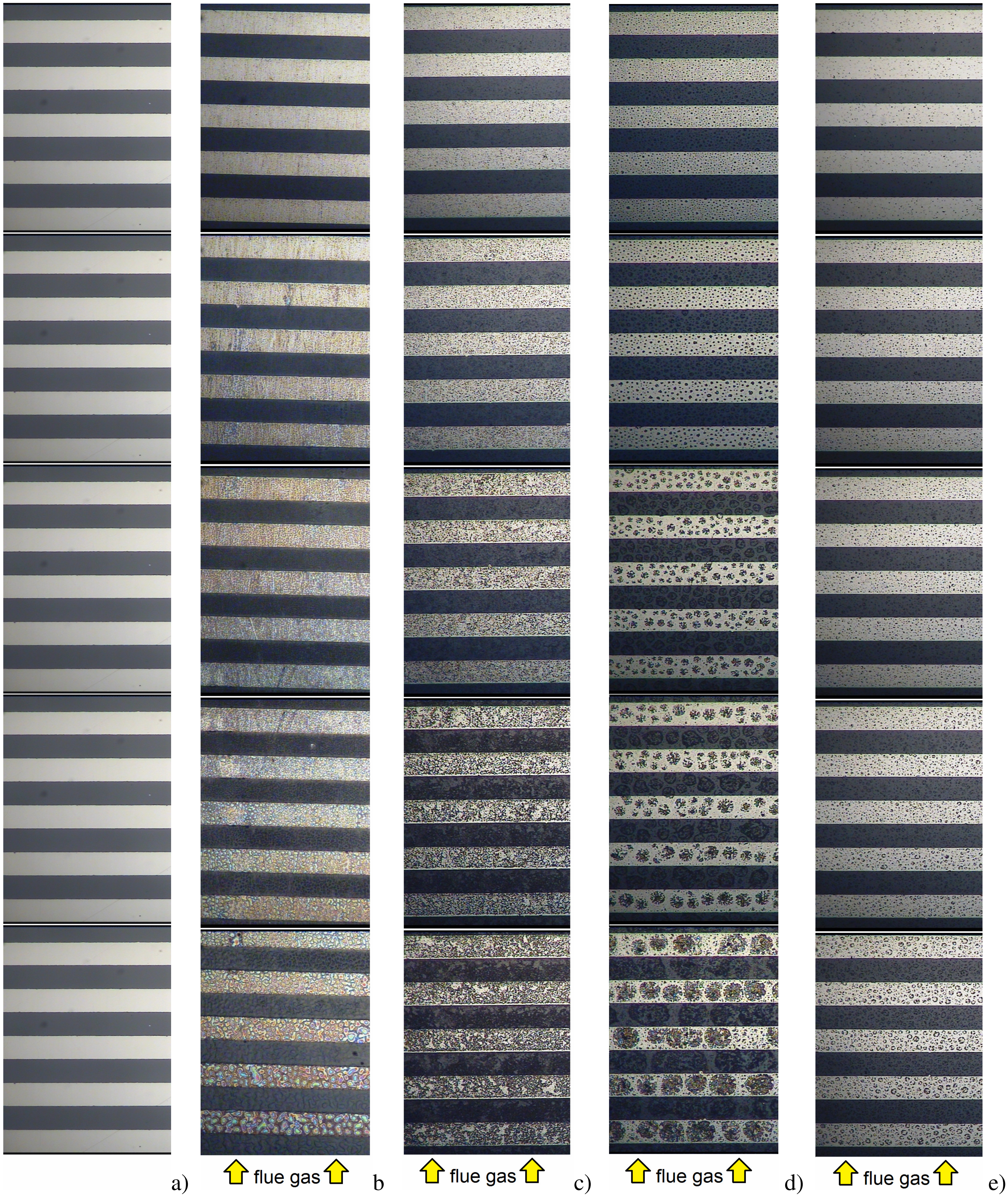


Figure: Successive snapshots revealing the results obtained after fumigation with the DEP-based separation device with l=d=100μm, h=2 mm, in the absence of fumigation and voltage a); at: U=12V, AC sinusoidal signal, f=50Hz, time of fumigation t=30s, b); U=37V, AC sinusoidal signal, f=50Hz, time of fumigation t=30s, c); U=12V, AC rectangular signal, f=100Hz, time of fumigation t=30s, d); and U=12V, AC rectangular signal, f=100Hz, time of fumigation t=30s, e).

Semi-quantitative analysis

- **Filtration (*F*)**

$$F = \frac{Max - Min}{Max} \quad [\%]$$

Table 1: Filtration results

Nr.	Probe	U(V)	f(Hz)	signal	Max	Min	Filtration
1	19,06	12	50	sin	21563	5775	**0.73**
2	16,10	37	50	sin	21775	10170	**0.53**
3	17,10	37	100	square	15107	3970	**0.74**
4	30,10	12	100	square	19487	5880	**0.70**

- **Recovery (*R*)**

$$R = \frac{Total - Reference}{Total} \quad [\%]$$

Table 2: Recovery results

Nr.	Probe	Total	Reference	Recovery
1	19,06	85023	15370	**0.82**
2	16,10	100372	15370	**0.85**
3	17,10	57012	15370	**0.73**
4	30,10	91083	15370	**0.83**