# Low temperature regenerating catalytic DPF

**Eugenio Meloni,**[a]* **Vincenzo Palma,**[a]

[a] *University of Salerno, Department of Industrial Engineering, Via Giovanni Paolo II, 132 – 84084 Fisciano (SA) - Italy*

*Corresponding author: emeloni@unisa.it*

**Abstract:** The wall-flow Diesel Particulate Filter (DPF) is the most common after-treatment system used to meet the particulate emission limits imposed by government regulations. It consists in alternately plugged parallel square channels, so that the exhaust gases flow through the porous inner walls leading to particles trapping. The consequent pressure drop increase requires DPF periodic regeneration. The results of our deposition and on-line regeneration tests on uncatalysed and Copper-Ferrite catalysed DPF, showed that the catalyst addition and the simultaneous use of microwaves during the regeneration step at lower gas flow rate, allows to reduce the energy supplied and the regeneration time.

**Keywords:** DPF regeneration, soot abatement, catalytic DPF.

## 1. Introduction

Nowadays in order to contain pollutants and $CO_2$ emissions produced by internal combustion engines, the OEMs have focused their attention on engine design and after-treatment development. Diesel engines have been widely used thanks to good performances in terms of fuel consumption, drivability, power output and efficiency. Moreover, the high heterogeneity of the charge in the combustion chamber leads to a simultaneous production of NOx and soot emissions, two pollutants very harmful to the environment[1]. The current Euro-6 legislation for light-duty vehicles imposes very strict targets to be reached for these pollutants, and these standards are difficult to meet with combustion optimization techniques. Some strategies were applied by automotive industries, such as the improvement of the spray atomization, the implementation of innovative Low Temperature Combustion processes, but it's not enough[2]. In such a scenario it is clear that the after-treatment is mandatory and Diesel Particulate Filter (DPF) is the most common system available on commercial vehicles, assuring the best compromise between filtration efficiency and pressure drop performance, and effectively reducing PM mass as well as the number of particles in a wide size range, including ultrafine particles[3]. Wall-flow DPF consist of a series of parallel channels alternatively plugged at each end to force the exhaust gas flow through the porous filter wall. During engine operation, the soot is trapped in the filter with an increase of exhaust back-pressure, therefore a regeneration process is required. In our previous work we studied soot deposition and on-line filter regeneration, showing that the simultaneous use of microwaves and copper-ferrite catalytic filter at low gas flow rate allows to reduce the energy supplied and the regeneration time compared to that required for the uncatalysed filter[4]. The objectives of this work are to optimize the formulation of the copper-ferrite catalytic filter in order to simultaneously improve the catalyst MW dissipation efficiency and the final catalytic DPF performance, to maintain a sustainable pressure drop, and to verify the feasibility of this technology by assessing the energy balance of the regeneration phase in comparison with current regeneration technologies.

## 2. Experimental

Rectangular shaped (36 x 80 x 124 $mm^3$) silicon carbide (SiC) wall flow monoliths (Pirelli Ecotechnology, 150 cpsi) were selected as support for the preparation of the catalytic filters. The selected catalyst is based on $CuFe_2O_4$, due to its very well-known dielectric properties and good oxidation activity[5]. The catalytic DPFs were prepared according to the previously optimized preparation procedure[5], by repeated impregnation steps in the precursors solution, drying at 60°C and calcination at 1000°C after each impregnation, in order to obtain a load of active species up to 30%wt. Before the impregnation steps, the SiC samples were dipped in the 1:1 mixture of $HF:HNO_3$ at a temperature of about 45°C for a time ranging from 5 to 30 minutes, with the aim to optimize an acid treatment able to increase the average pore diameter of the bare SiC filter. The prepared filters were characterized by means of several techniques, including SEM-EDX analysis, Hg porosimetry, Specific surface areas (SSA) measurements through $N_2$ adsorption at -196°C, applying BET method. The filters were then wrapped in an expanding intumescent ceramic-mat (Interam by 3M) which expands with heat, and enclosed in a stainless steel wave guide. A well-equipped diesel emission control system was built to perform the experiments: it includes a 505 $cm^3$ city car diesel engine, a diesel particulate filter system, a microwave energy supply system (Fricke and Mallah Microwave Technology GmbH), an

AVL 439 opacimeter, a differential pressure sensor, a temperature measurement system, an on-line gas analysis system for the continuous monitoring of CO, $CO_2$, NO, $NO_2$, $SO_2$ and $O_2$, a data acquisition system in Lab-View Ambient to log all the analogical signals.

**3. Results and discussion**

The selected erosion procedure allowed to obtain the increase of the average pore diameter in the bare SiC filter from 17 μm to 22 μm after 30 minutes of dipping in the acid solution. This value of time is to be considered as the optimal one for the pretreatment of SiC monoliths in the selected acid solution, since their gradual weakening for higher dipping times was observed. The effect of the dipping time in the acid solution was also evaluated in terms of specific surface area, and the results showed an increase from 0.35 $m^2/g$ up to 2.20 $m^2/g$ with dipping time increasing from 0 to 30 minutes. After the deposition of the active species both SSA and average pore diameter decreased, the first to 0.4 $m^2/g$ and the second to 15 μm. The on-line soot deposition and microwaves assisted regeneration steps were performed according to the previously optimized procedure[5]. The effect of modified porosity and $CuFe_2O_4$ loading on SiC monoliths is reported in Figures 1and 2 in terms of pressure drop (DP/DP0) during the soot deposition and the regeneration phase as function of the test time.

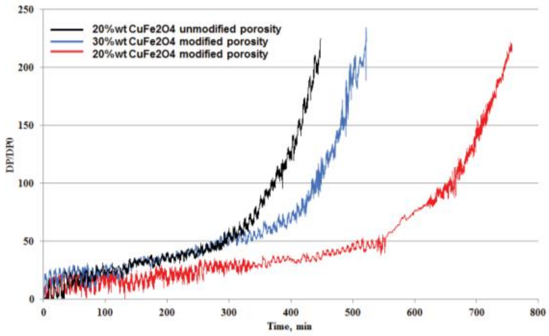


**Figure 1.** Effect of modified porosity and $CuFe_2O_4$ loading on SiC monoliths in terms of pressure drop (DP/DP0) during the soot deposition phase as function of the test time

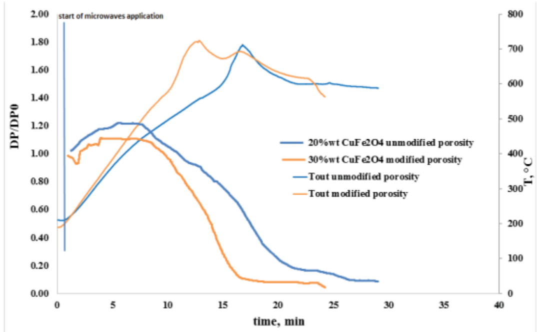


**Figure 2.** Effect of modified porosity and $CuFe_2O_4$ loading on SiC monoliths in terms of pressure drop (DP/DP0) and temperature profile during the microwave assisted regeneration phase as function of the test time

Figure 1 clearly evidenced the very positive effect that the porosity modifying procedure had on the filters performances in terms of deposition duration, since the time needed to reach the DP limit value corresponding to a soot load of about 5 g/l of filter for filters with the same active species loading (black and red curves) increased up to about 750 minutes. On-line regeneration tests performed using catalytic DPFs with 20% and 30%wt catalyst load (Figure 2) showed that the increase in the active species load resulted in a slightly lower catalyst threshold temperature value, higher reaction and heating rate, higher average filter temperature and faster regeneration, and, essential issue, in overall low energy consumption for the complete filter regeneration: the simultaneous use of MWs and $CuFe_2O_4$ loaded DPF allows to achieve an energy saving greater than 50% with respect to the traditional fuel post-injections regeneration technology.

**4. Conclusions**

The preliminary acid treatment of the bare SiC monoliths resulted in an increased average pore diameter of the catalytic samples, if compared with the analogues without acid treatment. The on-line soot deposition tests showed that, due to porosity modifying procedure, in the case of filters with the 20%wt copper ferrite loading the time needed to reach the DP limit value corresponding to a soot load of about 5 g/l of filter increases from about 450 to about 750 minutes, consequently decreasing the regeneration step frequency. In addition the further increase of copper ferrite loading up to 30%wt on a modified porosity filter resulted in a soot deposition phase time still longer than the one of the unmodified filter but with a lower loading of catalyst. This very important result allows to obtain two fundamental consequences, (i) to increase the duration of the deposition phase, and (ii) the higher catalyst loading resulted in a higher catalytic activity during the regeneration phase. Infact the filter with a simultaneous porosity modification and a higher catalyst loading (30%wt of copper ferrite) showed a threshold catalyst temperature decreased to about 350°C, and a regeneration step duration decreased from about 22 to about 15 minutes.

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