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Prototype For Real-Time Particle Elimination Instrument (PROSPEcT Deliverable 5)

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ABSTRACT

The main objective of this deliverable was to test a prototype device that employs a UV/ozone cleaning technique for the removal of carbon rich-contaminants from airborne nanomaterials (NMs). In principle this would remove a major component of non-engineered airborne NMs – soot-like particles produced by combustion processes - that would allow the easier detection of engineered, especially refractory, NMs. A prototype system was developed and tested. Preliminary results indicated that the prototype was not suitable for this purpose.

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1 INTRODUCTION.

An important aspect in nanomaterial research is the need to develop innovative strategies in order to improve some of the methods currently used. This report presents an overview of NPL's progress within Deliverable 5 of the PROSPEcT project: Prototype For Real-Time Particle Elimination Instrument. The prototype was tested using non-PROSPEcT powders. These were chosen as they were considered to be better indicators for the initial testing phase. Specifically, combustion-generated airborne soot was chosen as it was considered to be most relevant to the task of examining the efficiency of the UV/ozone cleaning prototype for the removal of carbonaceous background NM.

The UV/ozone cleaning technique was loosely based on the method used within NPL for surface cleaning of high precision standard masses.

2 METHODS.

The experimental scheme for testing of the UV/ozone prototype is illustrated in Figure 1.

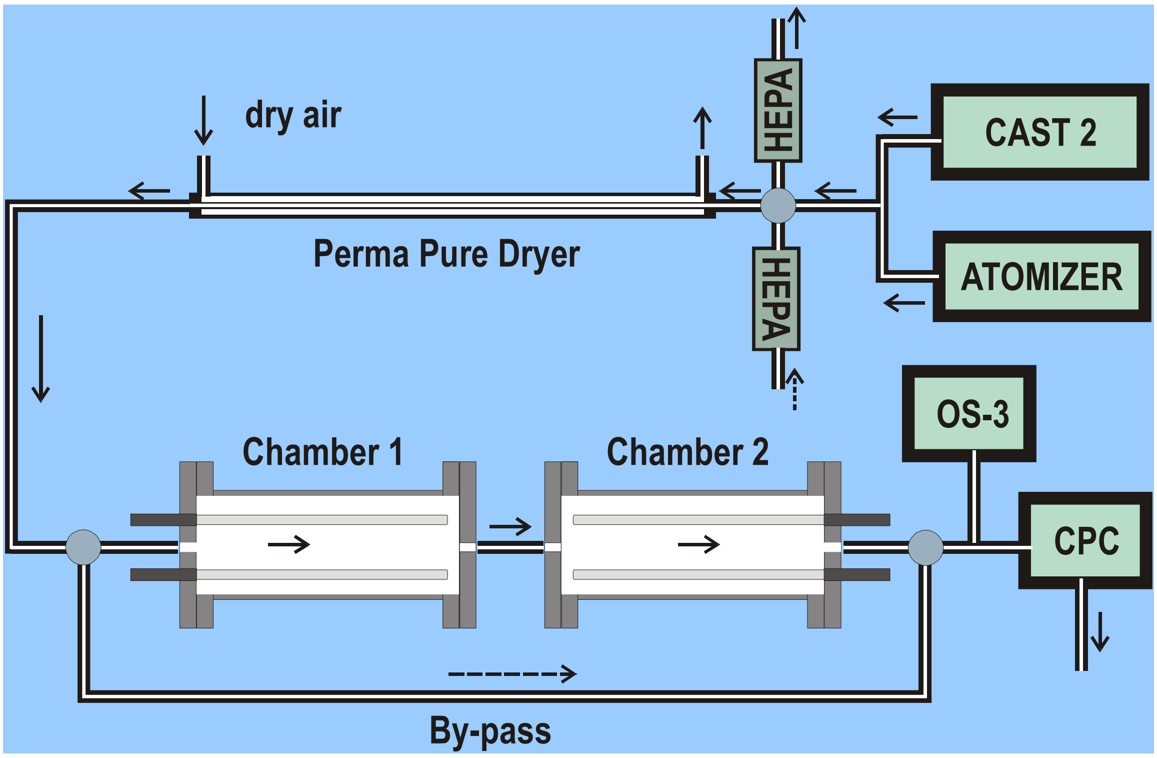

Figure 1: Schematics for testing of UV/ozone cleaning prototype, in order to distinguish from background (particularly carbon) particles

As shown in Figure 1, the individual components consist of:

- particle generator component (either the CAST 2 for the generation of carbon black (i.e. soot) or Atomizer, for the generation of sodium chloride and latex particles);
- a Perma Pure dryer, necessary when particles are generated from aqueous solution in the atomizer;

- 185 nm UV lamp in Chamber 1. Chamber 1 generates ozone, for ozone assisted cleaning; ozone gas can be generated in the air when molecular oxygen is irradiated with a UV-light of 185 nm;
- 251 nm UV lamp in Chamber 2. Chamber 2 serves the purpose in which ozone concentration will be reduced to a safe level prior to analysis; at this wavelength ozone molecules absorb the UV light and splits into a molecule of O_2 and oxygen atom;
- OS-3 ozone meter to monitor the concentration of ozone leaving the system;
- Condensation Particle Counter (CPC) for the measurement of particle number concentration.

3 PRELIMINARY WORK ON OZONE CONCENTRATION

Early work was devoted towards finding parameters for the UV lamps such that the ozone leaving the system was not too high. A mixing ratio of 0.1 molar ppm of ozone at a flow rate of 0.3 lpm was chosen as the target value.

Ozone generation was found to be more efficient than ozone removal, and more lamps were used in Chamber 2 than in Chamber 1.

The conclusions were:

1) with filtered clean air, chamber 1 could produce about 15 ppm O_3 while chamber 2 could reduce the O_3 concentration down to about 0.3 ppm and this could be further reduced by the addition of a fifth lamp in Chamber 2.

2) however, there appeared to be a particle generation process (presumably photochemical) involving the ozone generation/removal process that produced about a few tens of thousand particles per cubic centimetre. Clearly this was counterproductive to the main aim of the device.

3) the particle concentration could be reduced to around zero, but the ozone generating efficiency was reduced significantly.

Rather than spend an inordinate amount of time investigating the particle generation process, it was decided to move to direct tests quantifying the efficiency of the system in removing nanoparticles of different compositions.

4 RESULTS ON PARTICLE REMOVAL

The set up was used to test whether the UV/ozone cleaning principle can be used to distinguish between engineered and background particles (in particular carbon), by measuring the "removal ratios" of different type of nanoparticles when passed through the UV/ozone reaction chamber (Chamber 1). The "removal ratio" equates to:

$$\frac{\text{particle number concentration difference between when ozone cleaning was turned on and off}}{\text{particle number concentration when ozone cleaning was turned off}}$$

expressed as a percentage.

NPs were introduced separately into the system and the "removal ratio" of each type of nanoparticles measured. The results are presented in Figure 2.

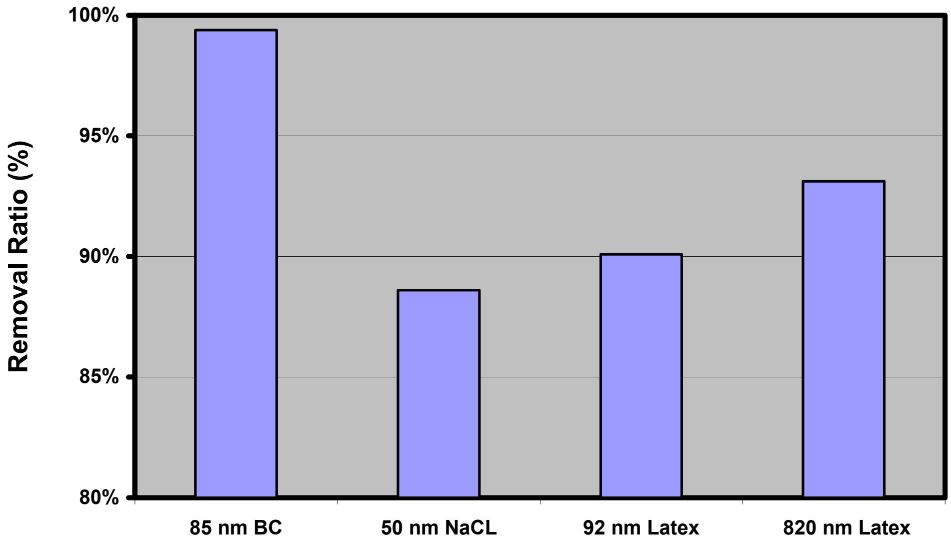

Figure 2: "Removal ratios" of different nanoparticles tested: 85 nm black carbon (BC), 50 nm sodium chloride (NaCl), 92 nm latex and 820 nm latex.

Results show that the "removal ratio" of BC (black carbon) is significantly higher than the others at around 99%. This is expected as UV/ozone cleaning is specifically geared towards reducing carbon content. However, the prototype was shown also to efficiently remove other types of nanoparticles, with removal ratios of: >90% for latex spheres (for both 92 nm and 820nm) and just under 90% for NaCl particles. This is not expected, as non-carbonaceous particles should be less sensitive to the UV/ozone cleaning process. Hence, it is likely that other mechanisms (in addition to the UV/ozone cleaning mechanism) are dominating the nanoparticle removal process.

Overall, the combination of issues of particle generation, and high removal efficiency for all particle types, showed that this prototype was unlikely to perform as well as necessary for the intended differential removal of background (carbon) nanoparticles.

5 CONCLUSION.

The conclusion was that the UV/ozone method being investigated for the removal of airborne carbonaceous nanoparticles would not be satisfactory as a method for discriminating between engineered (eg refractory) nanoparticles and background carbonaceous particles, because of the dual issues of particle generation within the ozone chambers, and the efficient removal of particles other than carbonaceous ones.

It is recommended that future work investigates other approaches to discriminating engineered nanoparticles from the non-engineered background.