Nanoparticle formation and emission mechanisms during laser melting and ablation of industrial ceramic tiles

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Abstract

During the last few years, there has been increasing evidence that workers in tile and ceramic industry are exposed to a considerable amounts of harmful airborne particles especially from the manufacturing of ceramics in furnaces [1-3].

In order to assess exposure to nanoparticle (NPs) emissions and their involved risks, particles emitted during the tile sintering using laser irradiation in a high-temperature furnace (continuous laser furnace) and during laser ablation were characterized. Six typical industrial tiles were selected, corresponding to commercial raw porcelain tile (#1), porcelain tile with frit (#2), porcelain tile with frit and colored decoration (#3), raw red clay tile (#4), red clay tile with frit (#5) and red clay tile with frit and colored decoration (#6). Seven experiments using two different laser technologies were made: (i) laser treatment of each ceramic material (from #1 to #6) and (ii) laser ablation of #1 (corresponding to experiment #7). Quantitative NP levels were studied by monitoring real-time size-resolved aerosol concentrations in the size range of 5 nm to 20 µm at the emission source (ES) and the breathing zone (BZ). Offline techniques such as transmission electron microscopy (TEM) and Energy-Dispersive X-ray (EDX) spectroscopy were used to characterize the particles collected and determine their corresponding elemental composition.

Figure 1 shows the time series of the particle number concentrations and size of the particles emitted during each experiment both at the emission source and in the breathing zone. Figure 2 shows micrographs from the particles sampled at the emission. The results evidenced that:

- The red clay tiles emitted higher particle number and mass concentrations in comparison with porcelain tiles during the laser melting process;
- Emissions in terms of particle number concentration from tiles with frit (especially red clay; #5) were higher than from raw tiles or with decoration;
- Two different emission behaviors were detected, between porcelain and red clay tiles, strongly linked to T and composition;
- New particle formation processes (nucleation) were detected during thermal sintering of the tiles;
- Nanoparticle emission processes were detected during laser melting of the tiles;
- Spherical particles originated from fusion were observed by TEM images;
- NP emissions in terms of mass were highest during ablation process;
- The highest concentrations of potentially harmful metals were found in the ultrafine fraction < 0.25 µm.

It is recommended that pre-cautionary and protective actions should be undertaken based on the high NP concentrations recorded.

References

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2. Hirtle, B., et al., *Kiln emissions and potters' exposures.* Am Ind Hyg Assoc J, 1998. 59(10): p. 706-14.
3. Taylor, J.R., A.C. Bull, and I.o. Ceramics, *Ceramics Glaze Technology*1986: Institute of Ceramics by Pergamon Press.

Figures

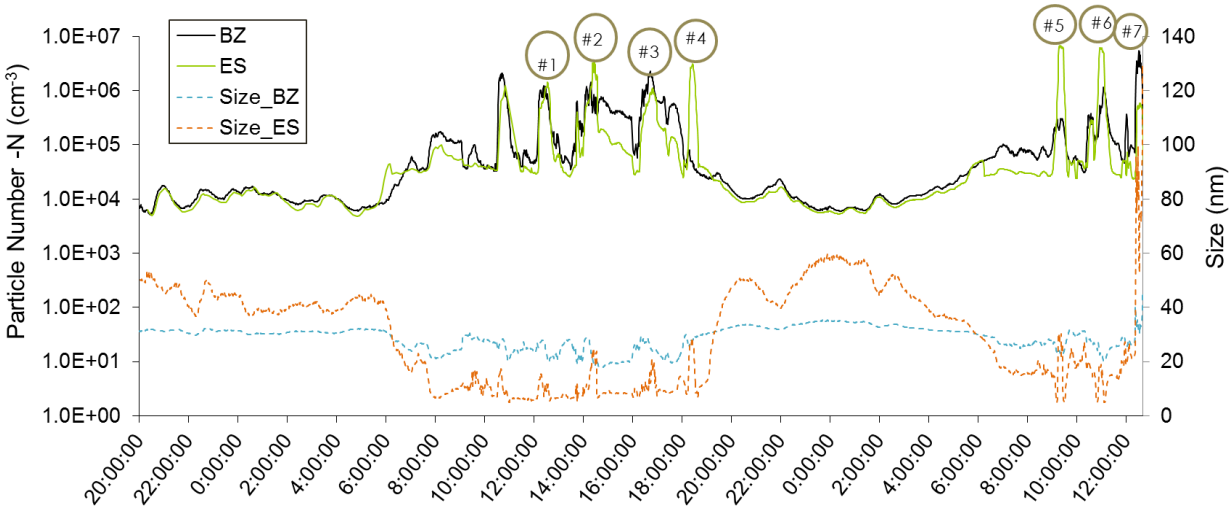

Figure 1. *Particle size diameter and particle number concentrations measured during each experiment in ES and BZ. The two different series in each plot represent number concentration of particles (solid lines) and corresponding particle size diameter (dashed lines).*

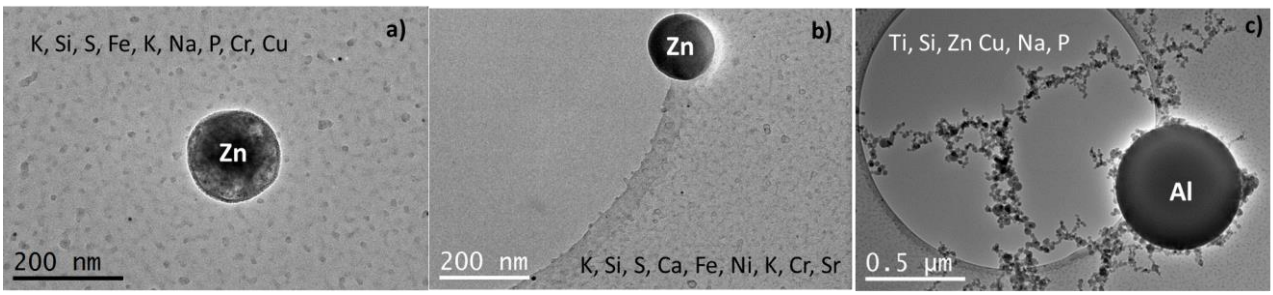

Figure 2. *TEM images of particles collected in ES during: (a) and (b) porcelain and red clay tile with frit manufacturing using laser melting technique in a high-temperature furnace (#2 and #5 respectively) and (c) raw porcelain tile manufacturing using laser ablation (#7).*