NANOPARTICLES EMISSIONS FROM MOLTEN METALS

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Introduction

- engineered nanoparticles and unintentional production of nanoparticles
- forming nanoparticles by dissipation or by thermal processes
- important source of contamination of working environment

The need to characterise the potential adverse impact of nanomaterials represents in the first step monitoring and control of air quality with respect to nanoparticles. Nanoparticles released to workplace atmosphere (both engineered NP and/or unintentional production of nanoparticles following various metal manufacturing processes) pose relatively not very well understood phenomena. The study of various nanoparticles has shown that they can pass biological barriers including cell membranes, many of them exhibit high mobility in environment and living organisms and some have negative health effects. Consequently, the investigation of possible health effects of nanoparticles started and nowadays it is a concern of several research projects including international ones. Nevertheless, the study of health effects is complicated and still in early stages and this is why the precautionary principle should be applied in occupational health and safety issues and environmental health consideration related to nanoparticles. The behaviour of engineered nanoparticles has attracted attention also to other type of nanoparticles in working and living environment, i.e. to non-intentionally produced nanoparticles. Among various types of engineered nanomaterials, large group is formed by metallic or metal-containing nanoparticles, e.g. nanomaterials based on silver, zinc oxide or titanium oxide. Many other metals are able to form nanoparticles either by dissipation or by thermal processes, what implies the idea, that nanoparticles are formed during common metallurgical processes as melting, founding or other manipulation with liquid metals. Nanomaterials produced by these operations may be an important source of contamination of working environment and environment generally by metal-containing nanoparticles.

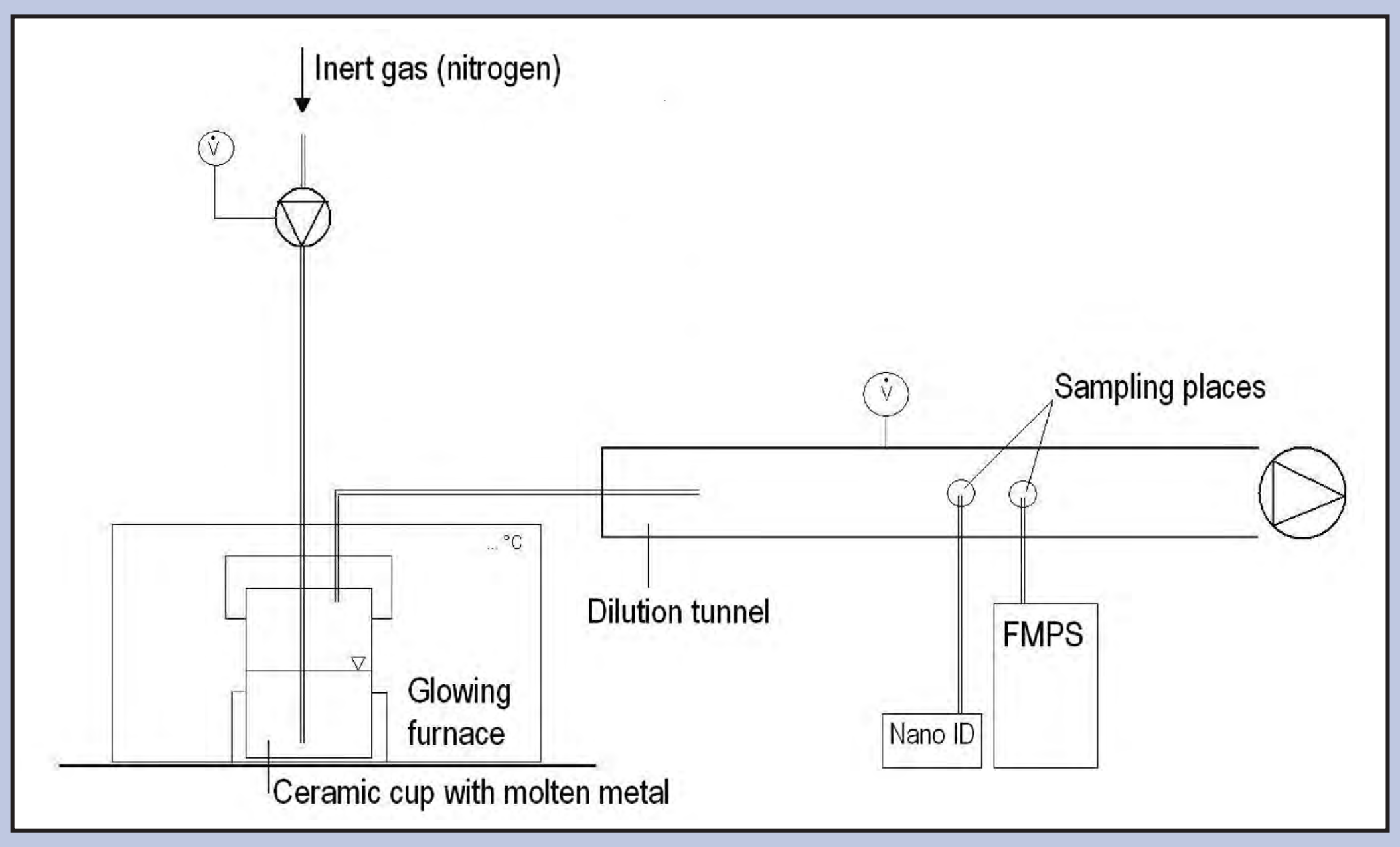

Fig. 1: Scheme of experimental set up

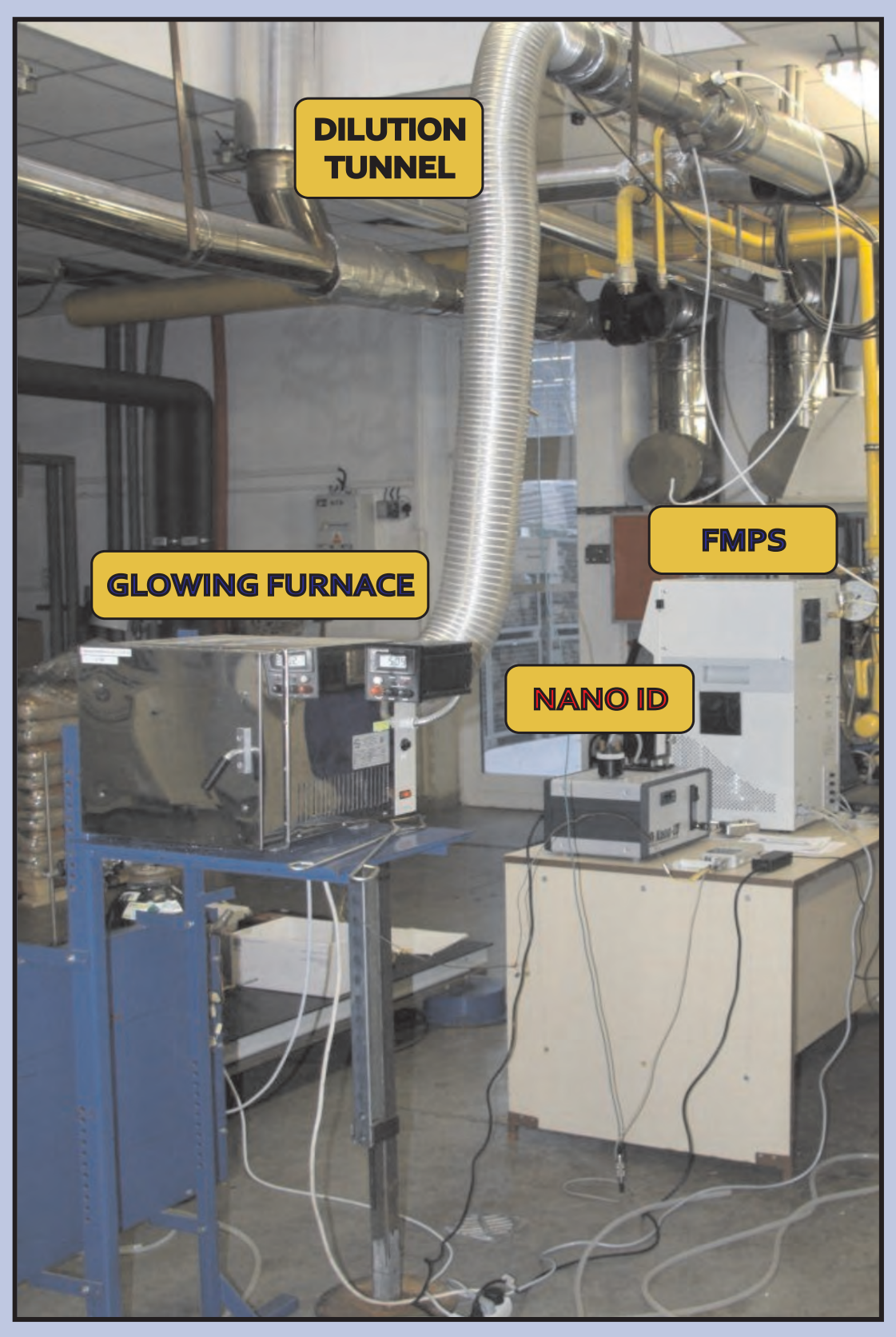

Fig. 2: Test furnace, tunnel and experimental apparatuses picture

Experimental method

- industrially used metals – Al, Pb, Sn, Zn, alloy Pb50-Sn50
- temperatures above melting point of metal
- particular nanoparticles aerosol fractions concentration measured by FMPS 3091 spectrometer

To examine the possibility of nanoparticles creation from molten metals in contact with gaseous phase, following pilot tests were realized: In the air-tightly closed ceramic cup, industrially used metals with low melting points (Al, Pb, Sn, Zn and alloy Pb50-Sn50) were melted and purged by nitrogen. The controlled flow of inert gas (nitrogen p.a., flow rate 165 and 270 ml/min) was introduces by peristaltic pump into ceramic cup. The molten metal exhalations were lead away into dilution tunnel, in which two orifices were placed and used for exhalation sampling. The conditions in the dilution tunnel were continuously monitored (temperature, relative humidity, air velocity), vide Fig.1 and Fig.2. Influence of metal temperature and volume of nitrogen bubbled throw molten metal was investigated. Temperatures 500, 700 and 900 deg C respectively (only above melting point of metal) were applied and particular nanoparticles aerosol fractions concentration in the range 5 to 100 nm measured by FMPS 3091 spectrometer. Samples of all tested metals and alloy aerosols were collected during the last test phase at the highest testing temperature by Nano ID WRAS sampler (Fig. 3) for subsequent SEM and ICP-MS analyses.

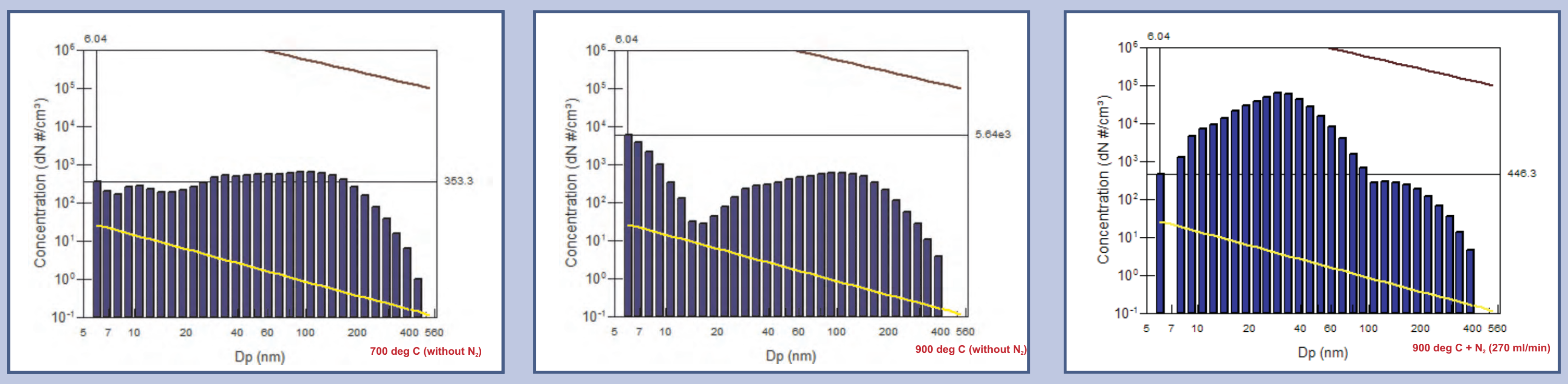

Fig. 3: Concentration distribution of tine nanoparticles

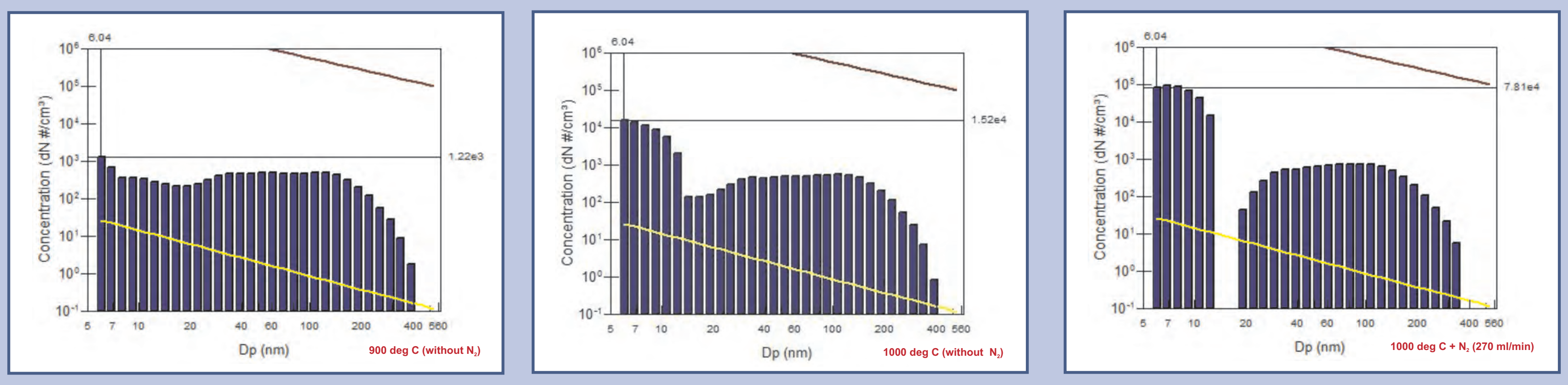

Fig. 4: Concentration distribution of aluminium nanoparticles

Results

- high temperature leads to production of fine nanoparticles
- difficult finding of common trend in behaviour of nanoparticles
- changes in fractioning

The experiments show that high temperature (900 deg C) leads to significant increase of fine NPs (5 – 12 nm) of all tested metals (Fig.3 and Fig.4). The relationship between metal vapour partial pressure and the quantity of distributed NPs cannot be clearly identified. Further, the relationship between purged nitrogen amount and quantity of distributed NPs is rather ambiguous. The experimental results suggest that there is changing of fractioning. Changing the dynamics of purged nitrogen changed distribution of NPs, what can be caused by different mechanisms of particles generation. The series of concurrent processes (evaporation followed by condensation, oxidation, splashing) are proceeding during the metal melting and differently sized particles are generated.

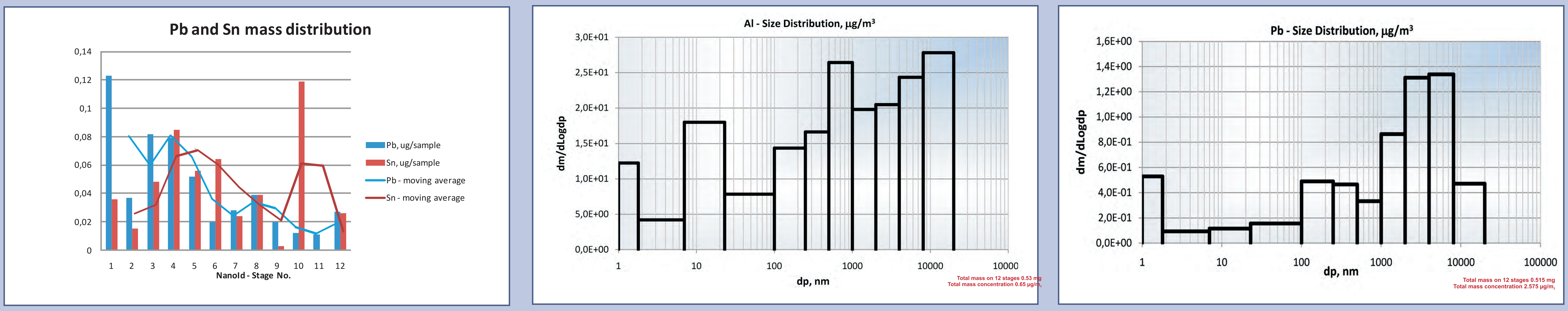

Fig.5: Mass distribution of Pb and Sn solder sample (ICP-MS) in 12 NanoID stages, normalised mass distribution of particular Pb and Sn metal in solder

STAGE	MINIMAL DIAMETER D_{min} (µm)	MAXIMAL DIAMETER D_{max} (µm)	SUBSTRATE	SIZE-MESH OPENING (µm)
1	20	35	galss slide	
2	8,1	20	galss slide	
3	4	8,1	galss slide	
4	2	4	galss slide	
5	1	2	galss slide	
6	0,5	1	galss slide	
7	0,25	0,5	galss slide	
8	0,06	0,25	FF filter	
9	0,015	0,06	nylon net	20
10	0,005	0,015	nylon net	20
11	0,0015	0,005	nylon net	41
12	0,001	0,0015	nylon net	120
8	0,06	0,25	FF filter	
9	0,015	0,06	stainless steel net	20
10	0,005	0,015	stainless steel net	20
11	0,0015	0,005	stainless steel net	36
12	0,001	0,0015	stainless steel net	125

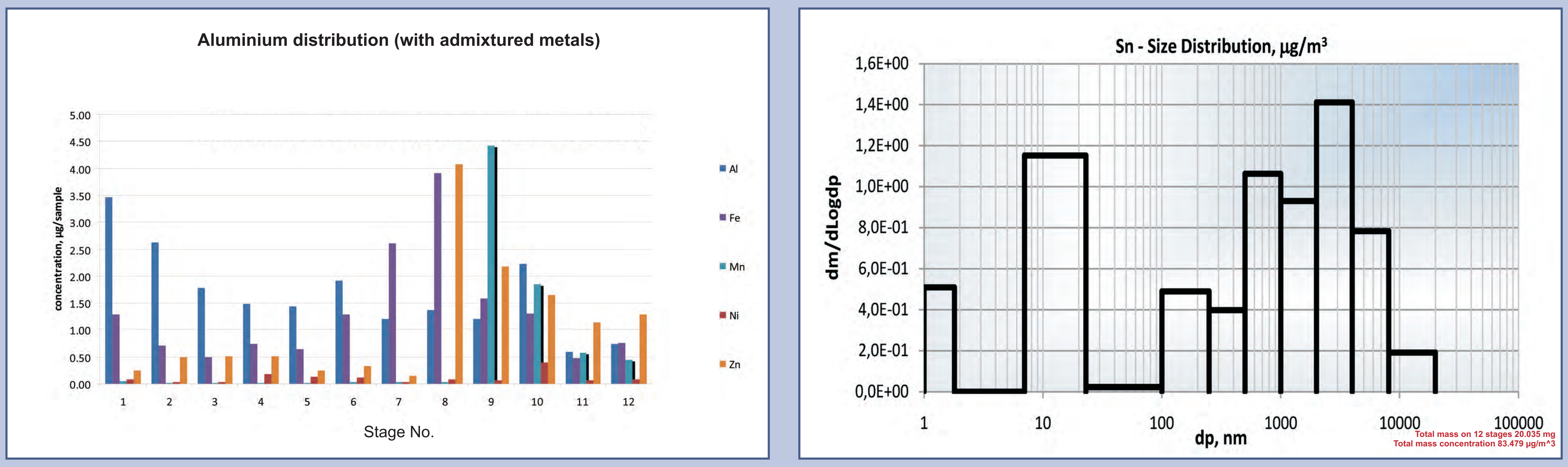

Fig.6: Mass distribution of aluminium (99.8% purity) and other elements in 12 NanoID stages, normalised mass distribution of Al

Discussion and conclusion

Understanding physical and chemical properties of engineered nanoparticles or uninten-tionally generated nanoparticles in industry is an essential task of health and safety supervisors and laboratories and providing mapping of environmental and occupational pollution by nanoparticles and estimation of worker´s personal exposure for further risk assessment. The results of this pilot test shall be exploited in immediate future in workplace exposure assessment methodology, as primary information about potential health risk for further risk assessment and management.