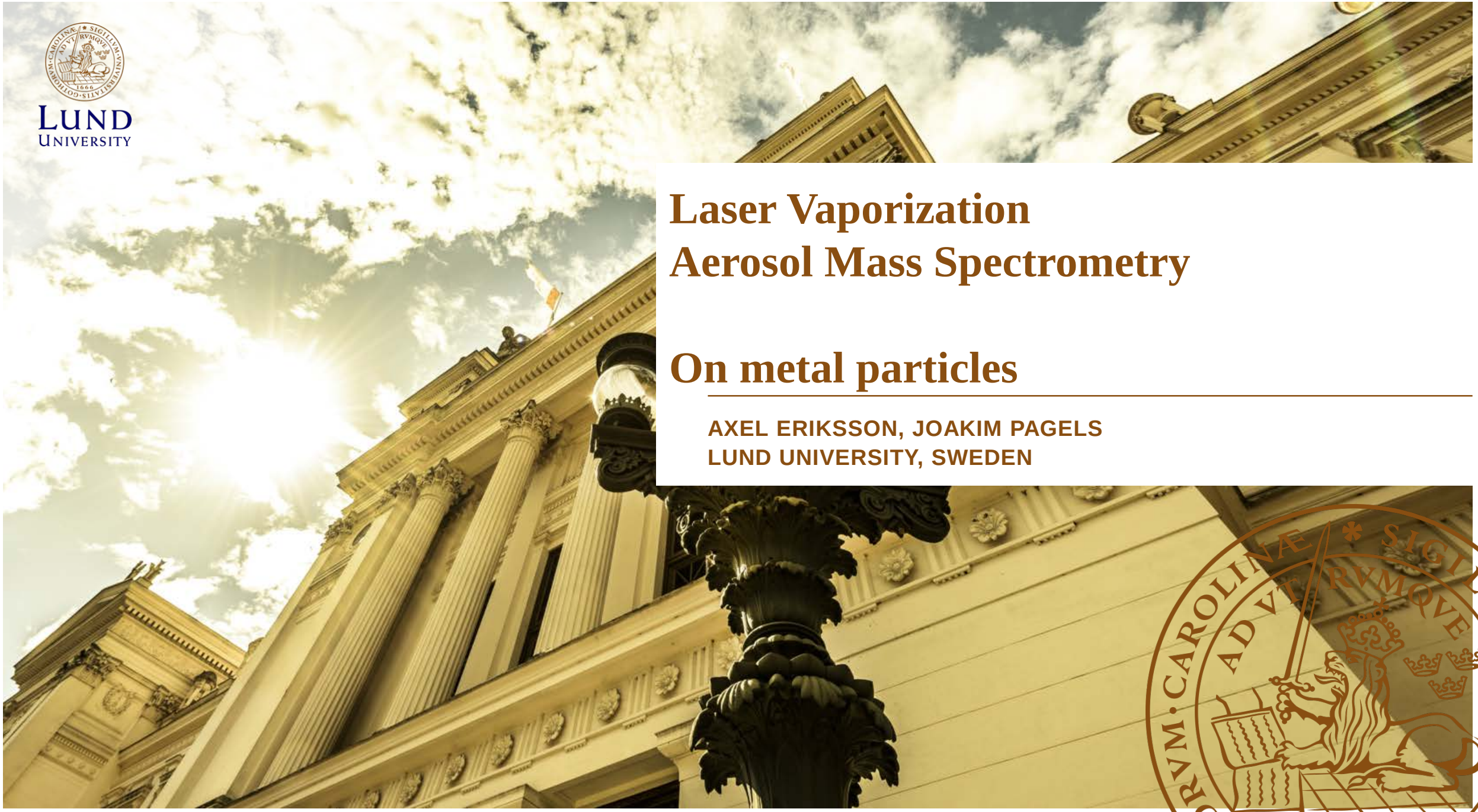


Laser Vaporization Aerosol Mass Spectrometry

On metal particles

AXEL ERIKSSON, JOAKIM PAGELS
LUND UNIVERSITY, SWEDEN

Metal detection conclusions

- Works (exception: Cu from spark discharge. CuO has low absorption at 1064nm)

- Apparent ionization efficiencies are low (for metal dominated particles); ~10 ions/pg (compared rBC, ~100 ions/pg, non-refractory, ~1000 ions/pg)
- More work needed: comparisons with reference [PIXE], compilation of absorption and ionization cross sections, energy needed to vaporize different particle types/components

- Sensitivity is high, few ions are required due to large mass defects and low ”closed” signal. Dynamic range is good (five orders of magnitude at high loadings)

Content

- Ambient/trace amount metals
- Engineered particles
- Welding fumes

Metals in ambient

“The inorganic and metals signals do not appear well correlated with the magnitude of rBC, […] suggesting that these species became associated with the rBC particles through secondary (i.e., gas-to-particle deposition or coagulation) mechanisms rather than being components of primary emissions.”

Onasch et al 2012.

Trace metals

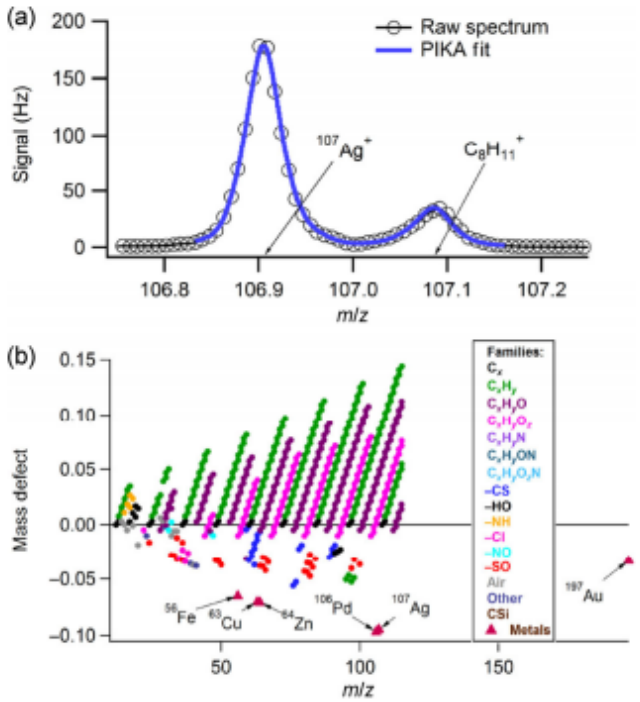
Table 2. Metallic ions evaluated in the laboratory experiment, electron impact cross section (σ), theory relative ionization efficiency (RIE_T), measured relative ionization efficiency (RIE_M), relative ionization efficiency ratio (RIE_T / RIE_M) and limit of detection.

Ion	σ (A^2) (70 eV)	Boiling point (°C)	RIE_{theory}	RIE_{meas}	RIE_{meas} / RIE_{theory}	LD (ng m^{-3})
Na^+	2.01[a]	879	0.77	20.30	26.36	51
Al^+	7.82[b]	2518	2.50	5.02	2.01	30
Ca^+	5.80[c]	1494	1.17	287.50	245.23	87
V^+	7.20[d]	3380	1.26	1.36	1.08	26
Cr^+	7.50[e]	2672	1.25	0.97	0.77	21
Mn^+	6.80[d]	2051	1.09	0.40	0.36	117
Fe^+	4.38[b]	2835	0.67	0.32	0.47	87
Ni^+	6.20[d]	2732	0.88	0.25	0.28	111
Cu^+	3.75[d]	2567	0.51	0.43	0.83	90
Zn^+	5.60[d]	908	0.74	0.73	0.99	n/a
Rb^+	7.20[e]	688	0.77	158.47	206.34	10
Sr^+	8.20[c]	1384	0.85	23.19	27.24	10
Ba^+	10.50[c]	1140	0.73	21.42	29.23	11
C_3^+	4.43[f]	4000	1	1	1	13[g]

[a] Fujii and Srivastava (1995), [b] Freund et al. (1990), [c] Vainshtein et al. (1972), [d] Lotz (1970), [e] Kim et al. (1998), [f] Naghma and Antony (2013), [g] LD value estimated for rBC.

2 min

Engineered metal particles



"The LV-AMS is used to characterize several types of metal nanoparticles (Ag, Au, Pd, PdAg, Fe, Ni, and Cu). The degree of oxidation of the Fe and Ni nanoparticles is found to increase with increased sintering temperature, while the surface organic-impurity content of the metal particles decreases with increased sintering temperature"

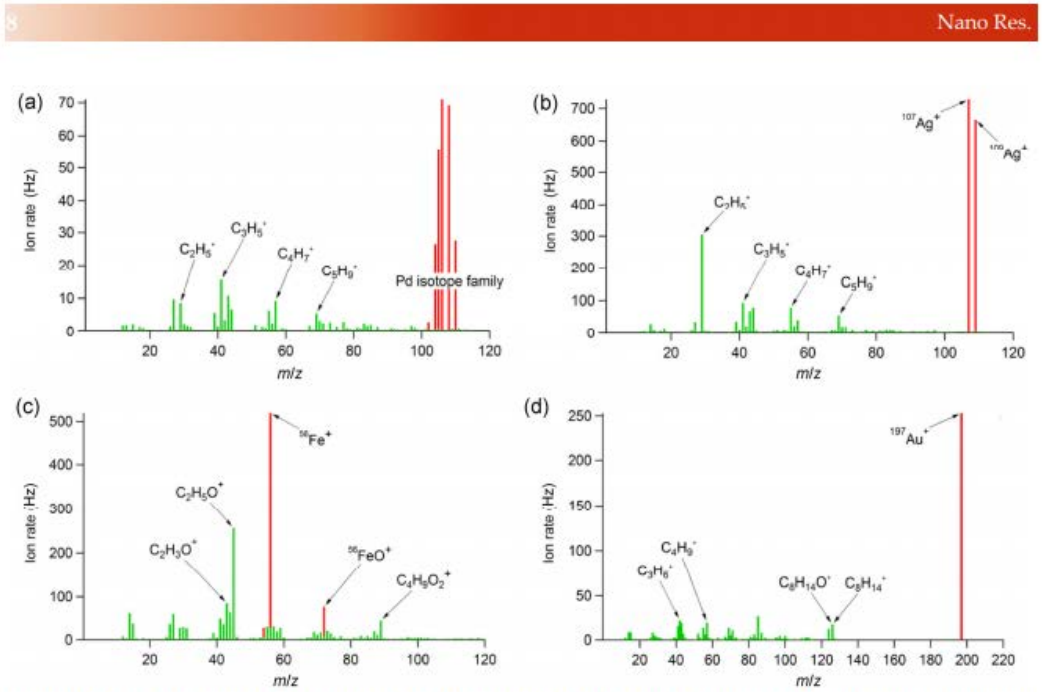
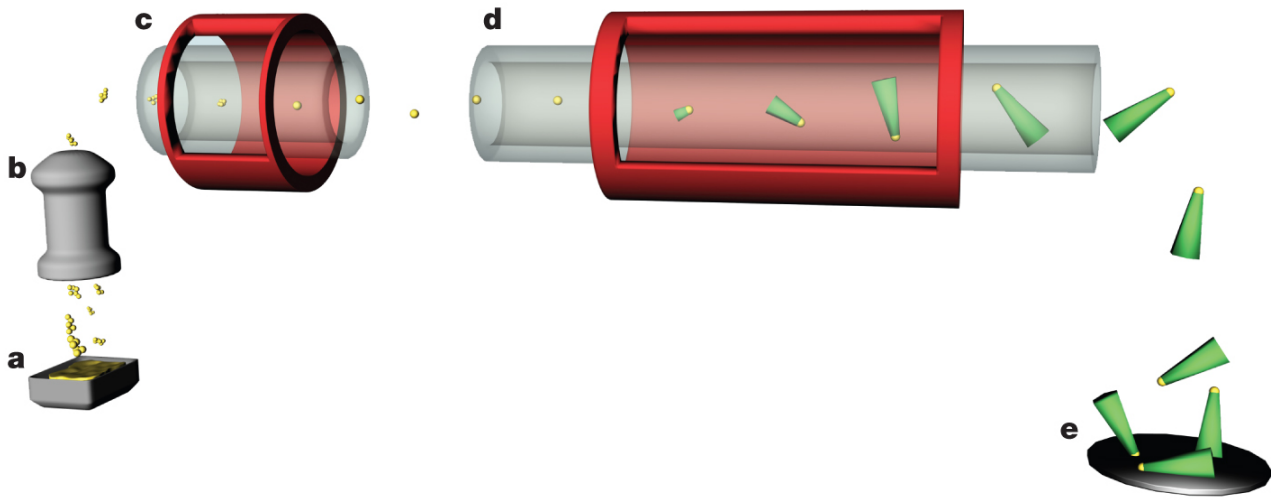


Figure 3 Mass spectra of four differently synthesized nanoparticles. Metal ions and fragments representing organic impurities are shown in red and green, respectively. (a) 100-nm semi-sintered Pd particles (SDG_C); (b) 100-nm semi-sintered Ag particles (SDG_C); (c) 110-nm sintered Fe particles (SDG_C); and (d) 40-nm sintered Au particles (HTF). The diameters are d_m.

Nilsson et al 2015

Aerotaxy growth of nanowires.

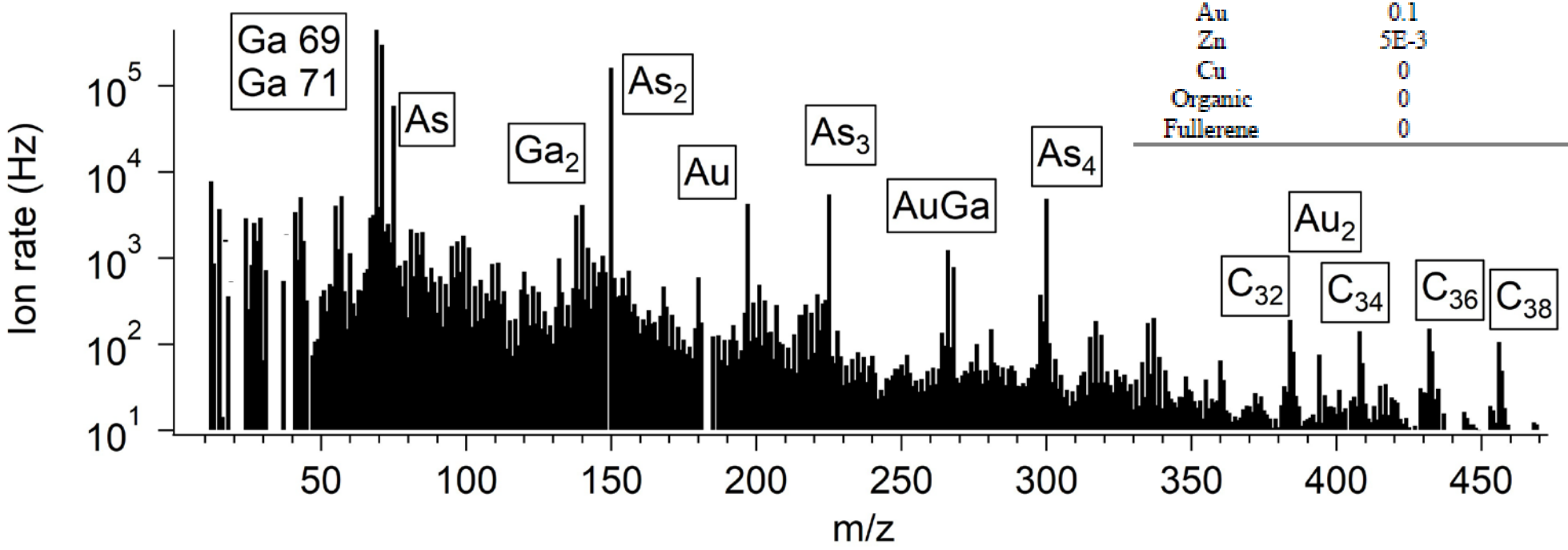


Au particles are sintered,
size selected with a DMA and
used to seed nanowires grown in
the aerosol phase.

80 nm Au seed, 3µm GaAs wire

Heurlin *et al.* 2012

Full mass spectrum GaAs NW:s



Component	Nominal mass fraction	Signal fraction
As	0.5	0.2
Ga	0.5	0.7
Au	0.1	5E-3
Zn	5E-3	3E-4
Cu	0	3E-5
Organic	0	0.1
Fullerene	0	5E-4

Signal intensities GaAs NW:s

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element	70 eV cross section [Å^2]	70 eV cross section/mass	boling point [C]
As	5	0.067	613
Ga	9.1	0.131	2400
Au	13.7	0.070	2700
Zn	3.66	0.056	907
GaAs			1238

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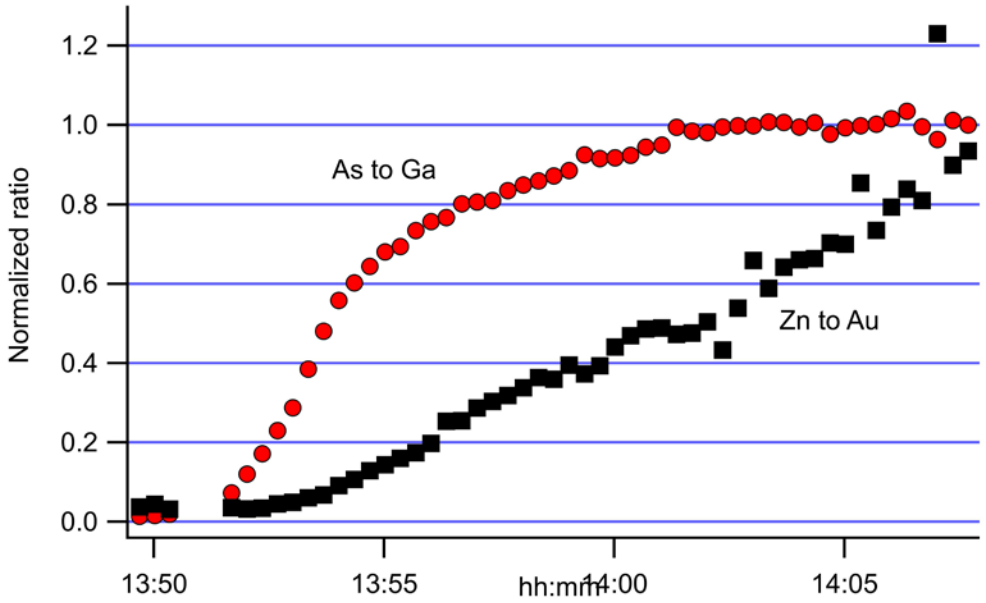
Au harder to vaporize than GaAs

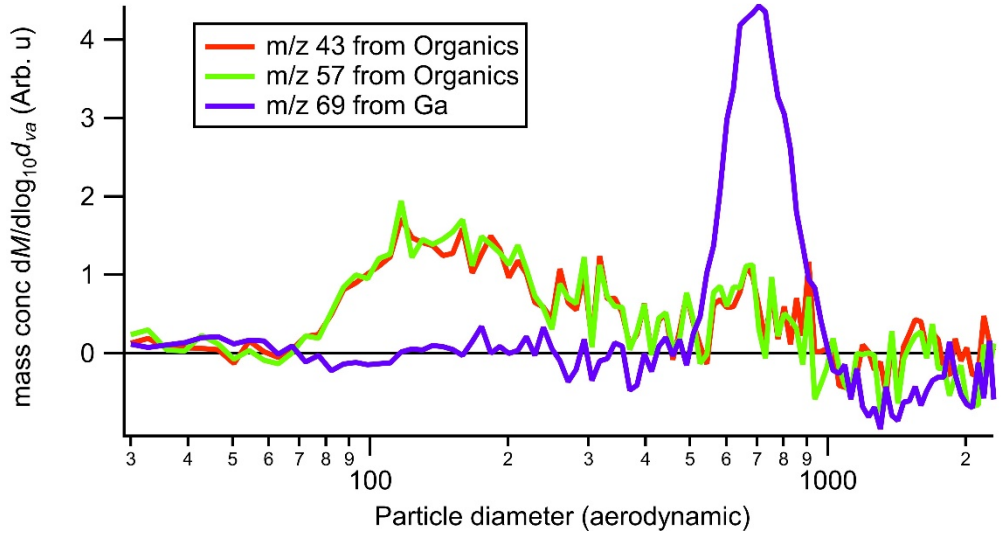
Incomplete GaAs vaporisation gives more As than Ga

Varorized wire, but only parts of Au seed?

Time resolved data GaAs NW:s



Size resolved data GaAs NW:s



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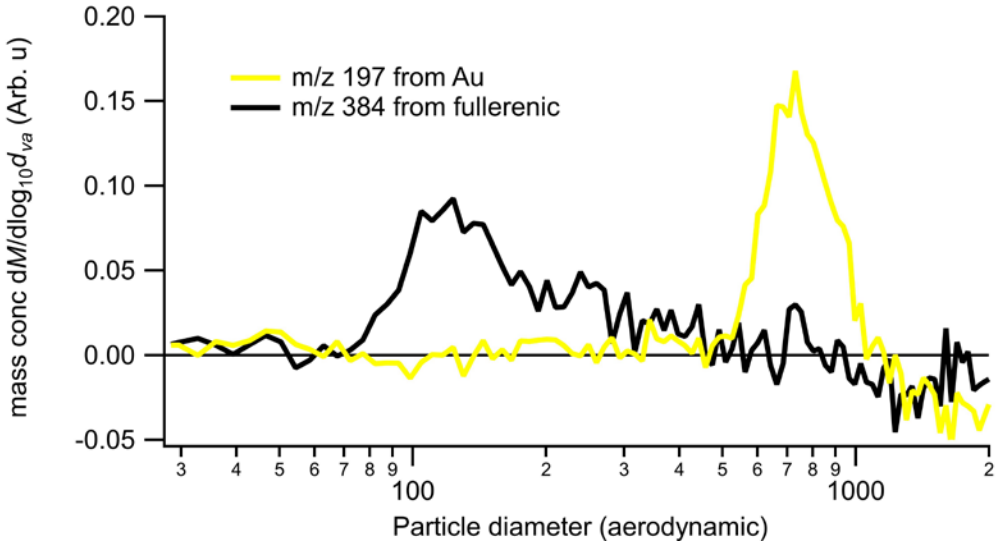
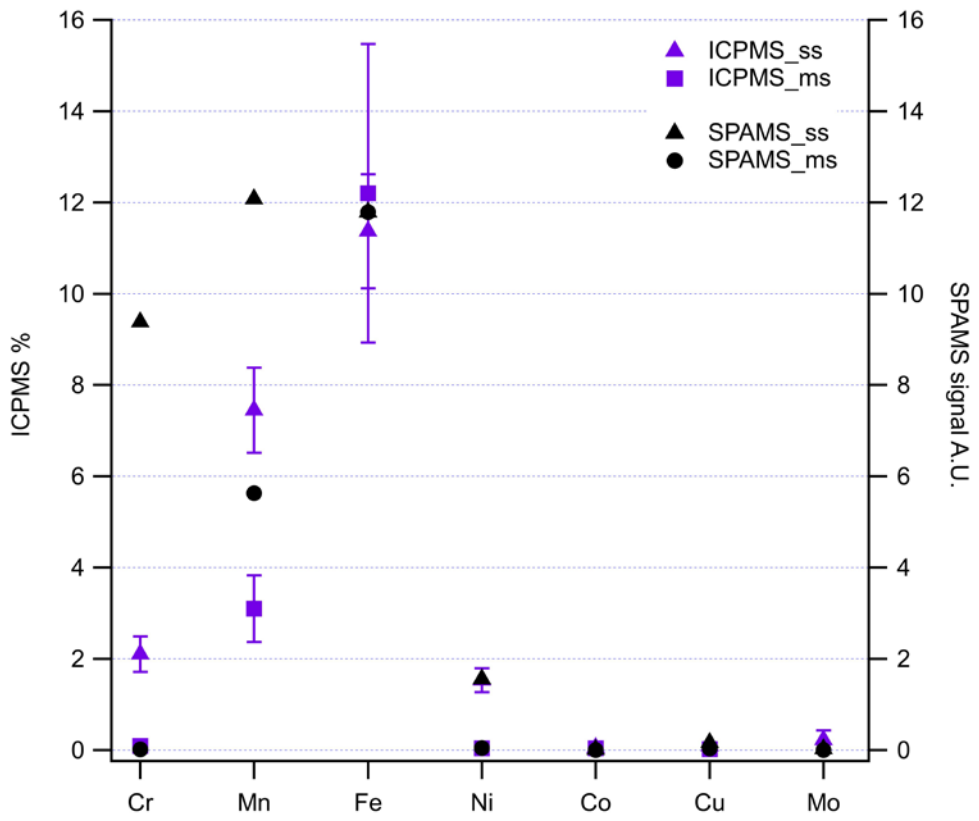
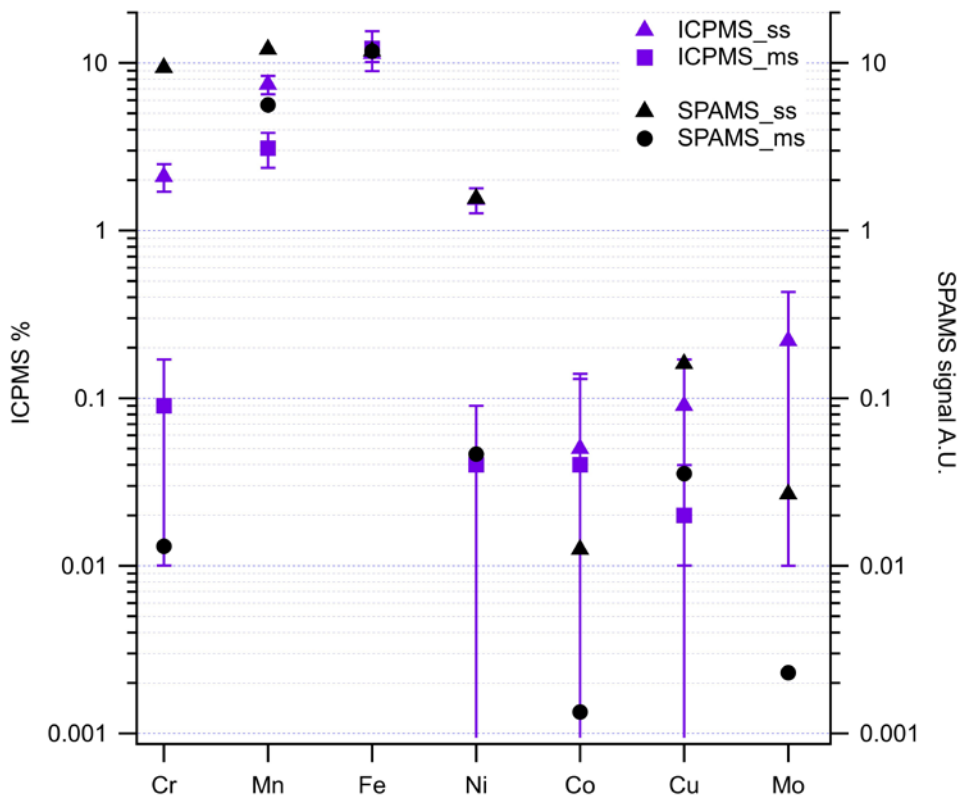


The mode at (aerodynamic) size 120 nm is tentatively attributed to carbonaceous impurities exiting the sintering oven

Most of organic impurities are present in this mode, e.g. externally mixed with the nanowires

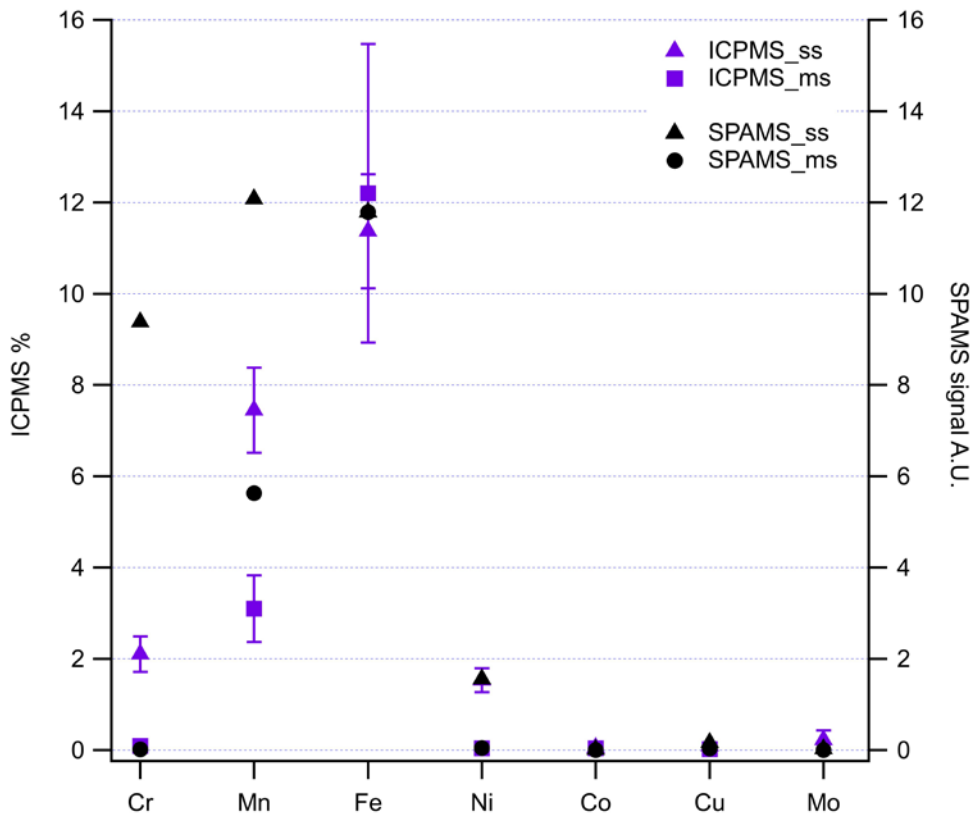
Welding fumes (preliminary)





ss: stainless steel ms: mild steel

Welding fumes (preliminary)



element	70 eV cross section [Å²]	70 eV cross section/mass	boiling point [C]
Cr	7.6	0.146	2670
Mn	5.99	0.109	2060
Fe	4.38	0.078	2870
Ni	6.2	0.106	2800
steel			1450-ish

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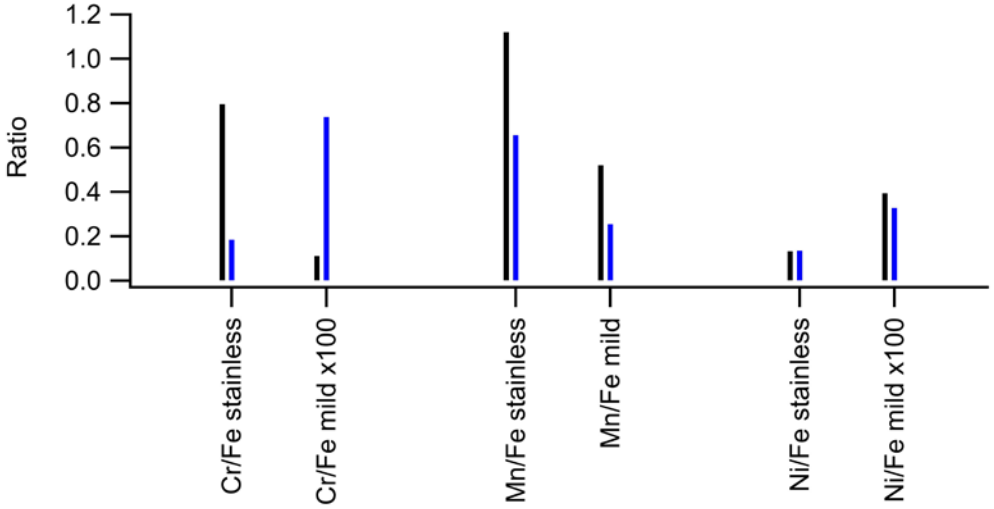

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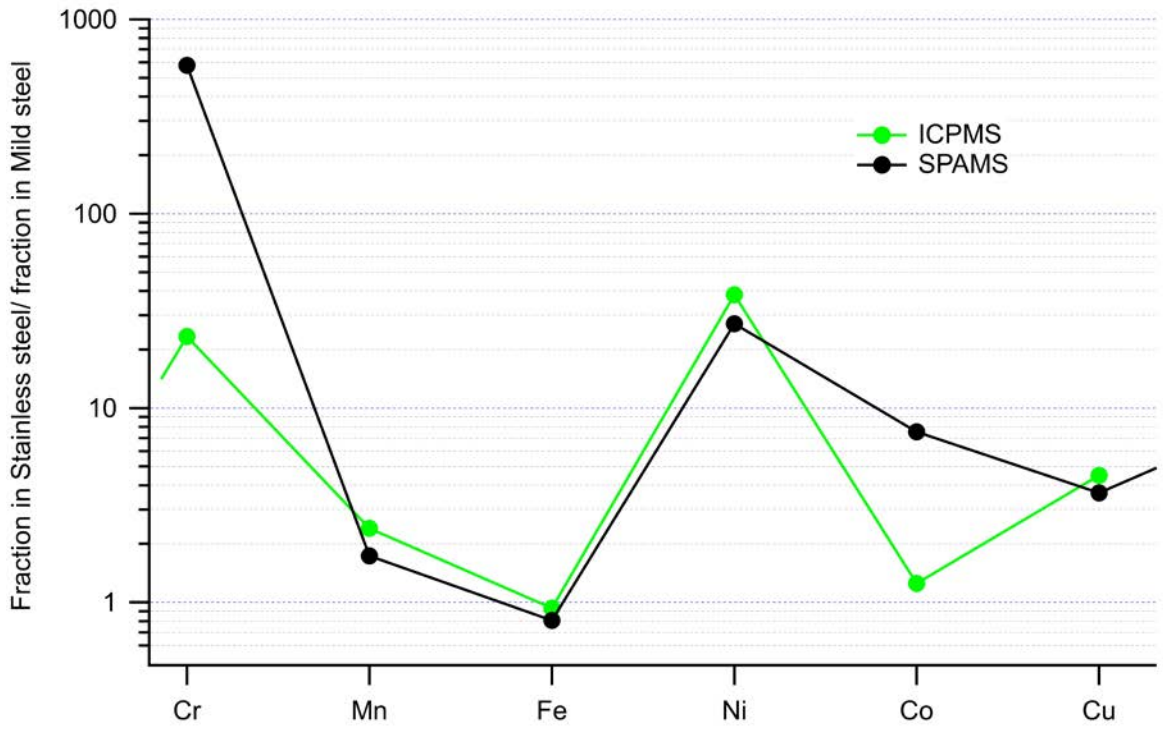

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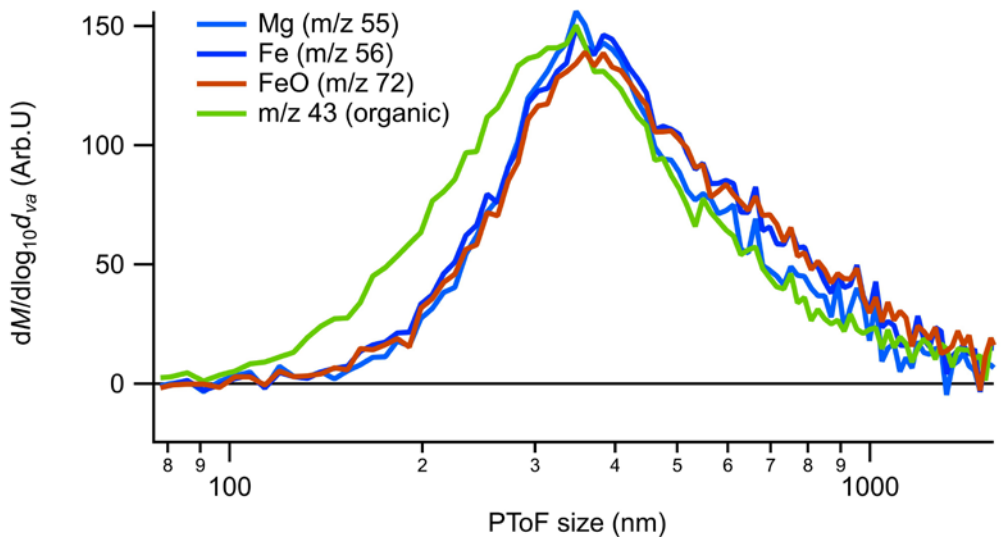

Welding fumes (preliminary)

Internal metal mixture,
Organic coatings?