GED

Gas Exchange Device

IAS Inc.

GED can measure ppq level of metallic particles in gases

The system was originally developed to analyze metallic particles in environmental air using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). It is now expanded to special gases used in semiconductor industry.

ICP-MS is one of the most sensitive analytical techniques to determine metallic elements in various samples. Since aqueous sample is basically introduced to the Ar plasma by means of a nebulizer and a spray chamber, gas analysis requires time consuming sample pre-treatment such as filtration and bubbling. In addition, it is extremely difficult to determine ppt or sub-ppt level impurities in semiconductor gases.

If gases can be directly introduced to the Ar plasma, metallic particles can be analyzed without the pre-treatment with much higher sensitivity. However, ICP-MS has limitation to introduce other gases into the plasma because it is difficult to sustain the plasma.

The *GED* uses a special membrane that can exchange other gases with Ar gas. The gas exchange efficiency is more than 99.99%. When a sample gas contains particles, the sample gas is exchanged by Ar gas and particles come out in Ar gas stream at the exit of *GED*, which can be directly introduced to the Ar plasma of ICP-MS and analyzed.

As a result, a single ppq level of metallic impurities can be analyzed directly.

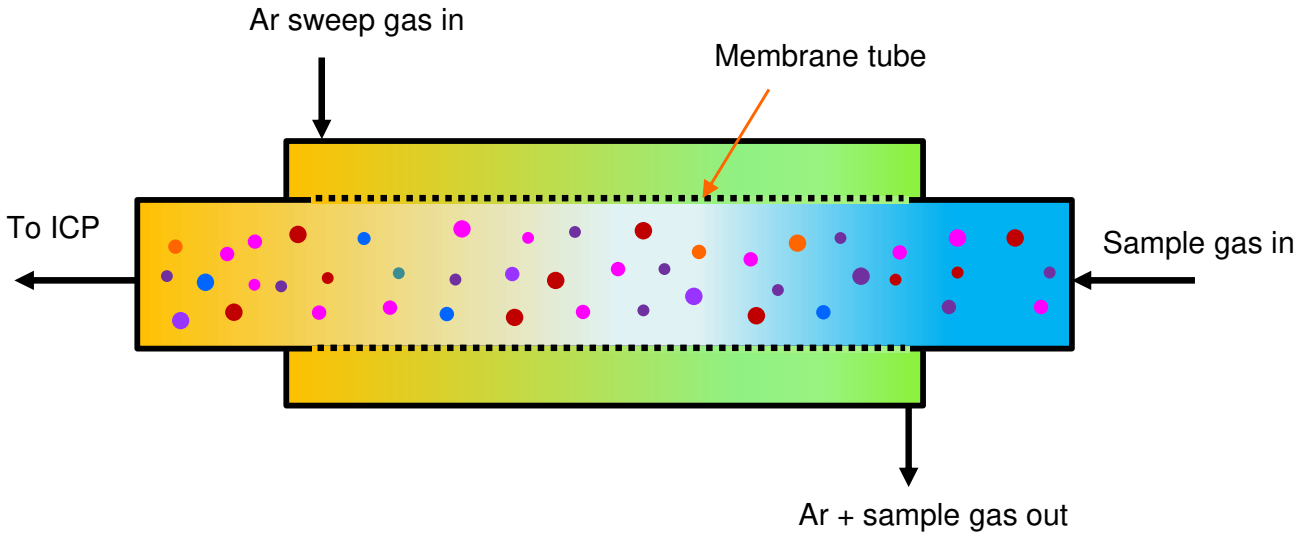


Fig.1 Principle of *GED*

The principle of *GED* is based on the Dalton's law and Graham's law. A sample gas is introduced to an inner side of membrane tube and Ar gas is introduced to an outer side of membrane tube as shown above. Since the partial pressure of sample gas inside the membrane tube is higher than the outside, the sample gas diffuses into the outside of membrane tube. On the other hand, the partial pressure of Ar gas outside the membrane tube is higher than the inside, the Ar gas diffuses into the inside of membrane. Ar sweep gas flow is much higher than the sample gas flow and the sample gas is completely replaced with Ar gas (>99.99%) while particles don't pass through the membrane and remain inside the membrane tube. As a result, the particles come out from *GED* in Ar gas stream, which are introduced to the Ar plasma of ICP-MS and analyzed.

Major applications:

◆ Environment

- There are 30 - 60 ng/m^3 of Pb and 0.1 - 0.3 ng/m^3 of U in normal environmental air. Many ^{208}Pb particles were detected with 10 msec integration time per point as shown in Fig.2.
- ^{235}U and ^{238}U in environmental air were also detected with 10 msec integration time and 10 sec integration time as shown in Fig.3. Shorter integration time can detect individual particle and longer integration time can accumulate particles that gives accurate quantitation analysis.
  The natural abundances of ^{235}U and ^{238}U are 0.72% and 99.27%, respectively, and the results with longer integration time showed good isotope ratio agreement.
- Fig.4 show the results of ^{56}Fe particle analysis inside and outside a clean room. Outside clean room showed significant amount of ^{56}Fe particles.

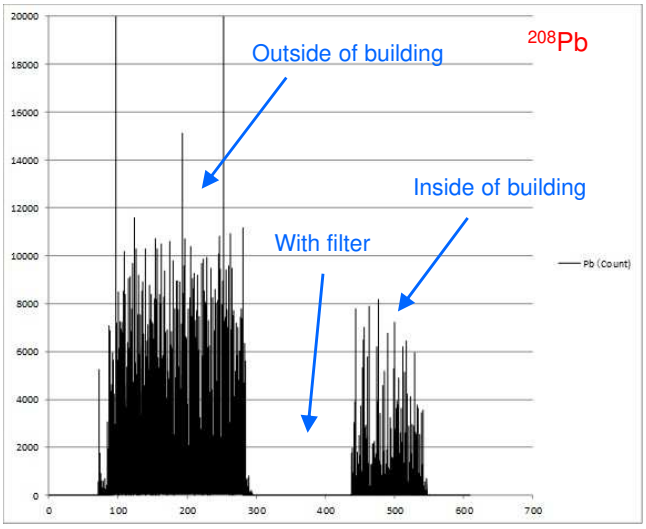
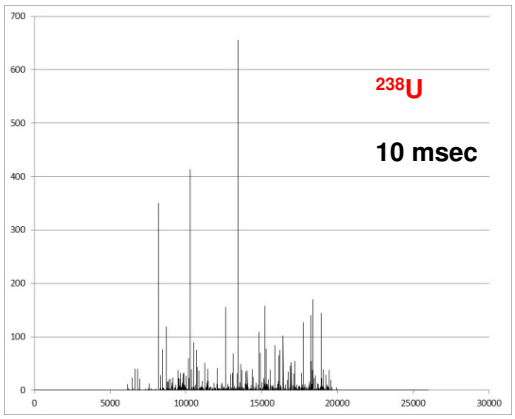
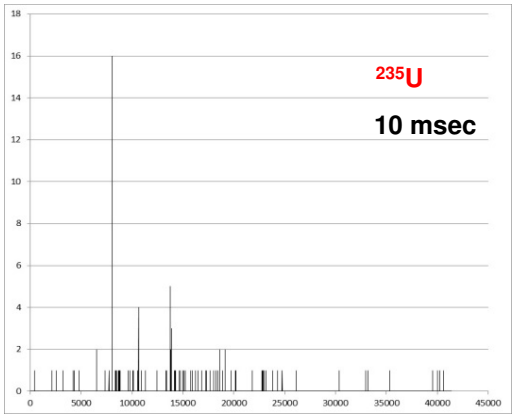
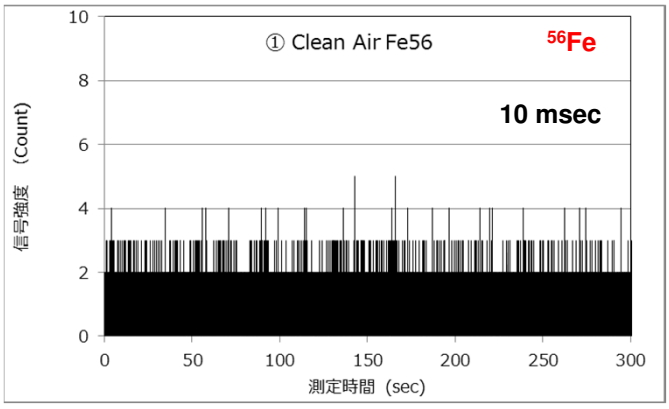


Fig.2 ^{208}Pb in normal environmental air







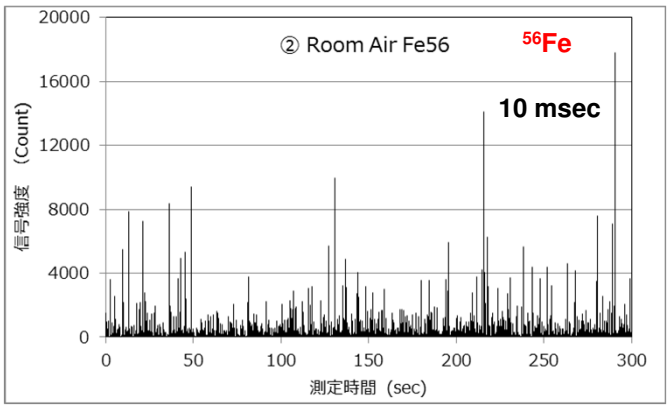


Fig.4 ^{56}Fe environmental air inside (upper) and outside (lower) clean room

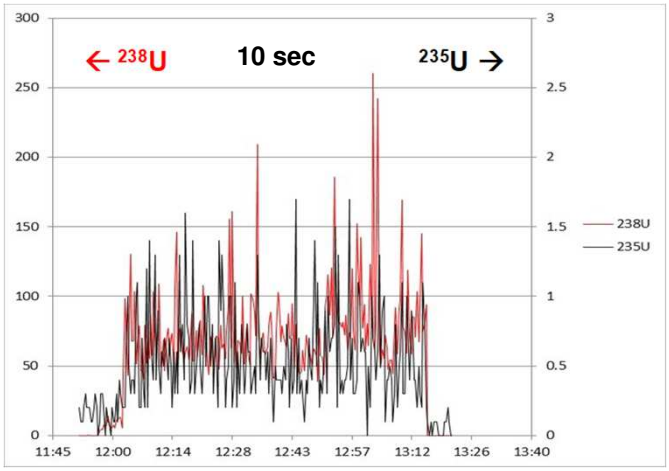


Fig.3 ^{238}U and ^{235}U in environmental air

◆ Semiconductor

- NH_3 gas used for semiconductor industry was analyzed. Fig.5 represents the transient signals with 1 msec integration time with and without the filter. As clearly seen on the left hand side, many particles such as Cu, Zn and Pb were detected without the filter. The Cu concentration detected are around 0.03 ppt(wt).

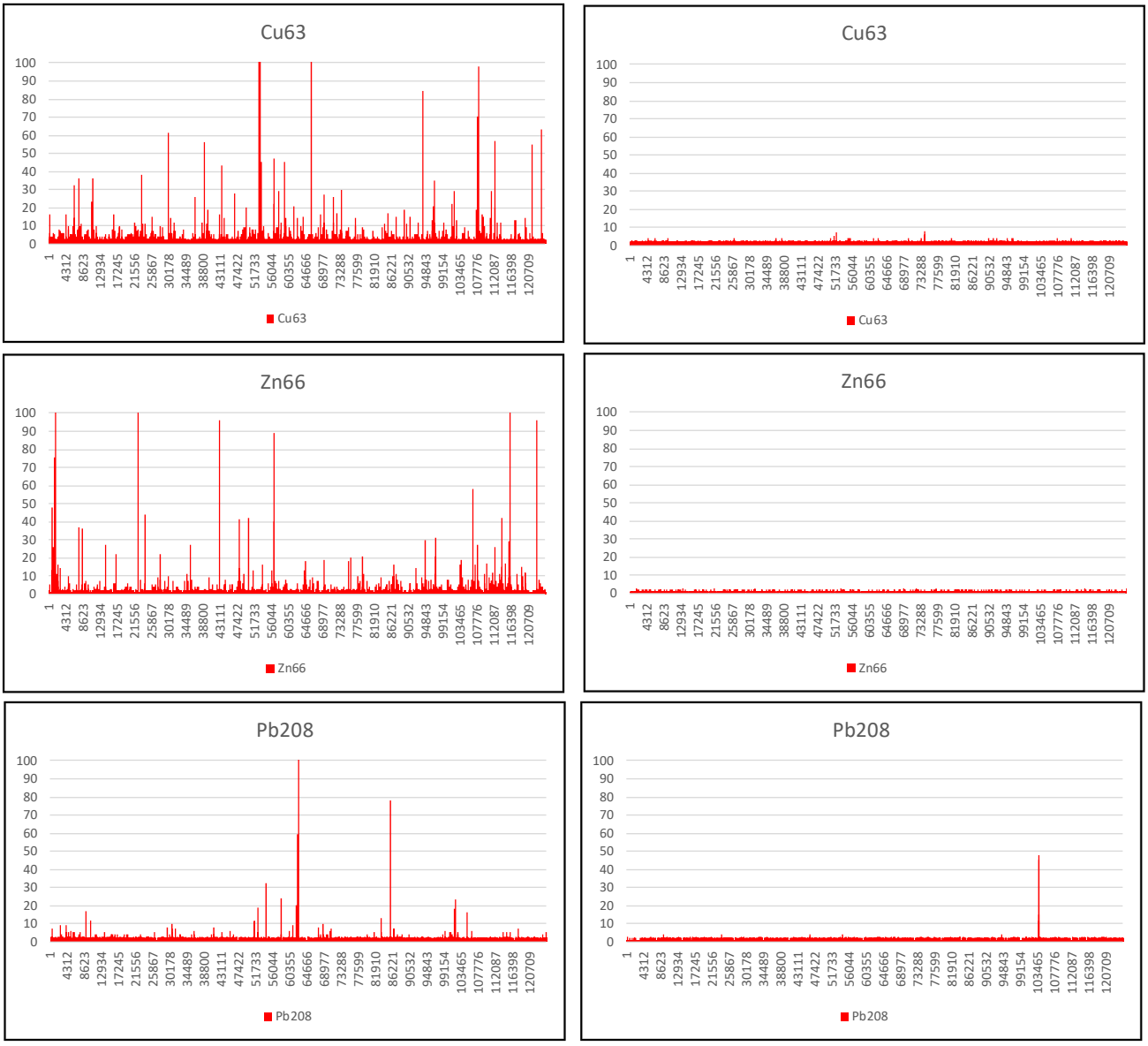


Fig.5 ^{63}Cu, ^{66}Zn and ^{208}Pb signals with 1 msec integration time without (left) and with (right) filter

- Analysis of gaseous compounds in air such as SiH_4, PH_3, AsH_3, GeH_4, SbH_3,and Hg can be analyzed using GPD-GED-ICP-MS.
- Fig.6 represent calibration curves of AsH_3 and GeH_4 in clean room air. Hydrides of these compounds are converted to oxide particles by *GPD* prior to GED-ICP-MS.

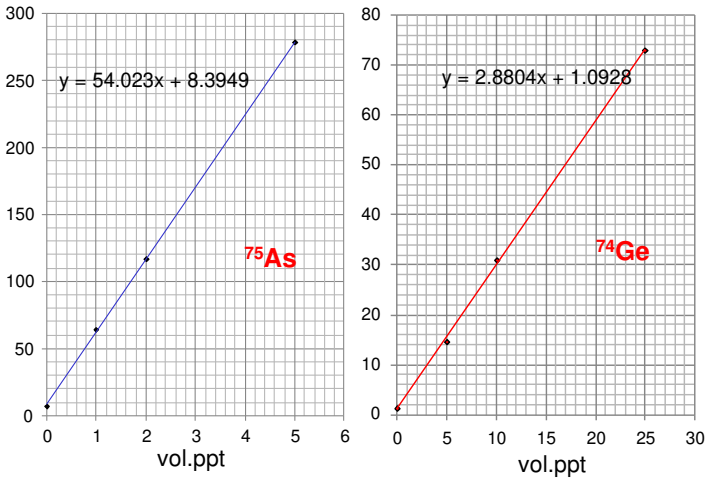


Fig. 6 calibration curve of AsH_3 (left) and GeH_4 (right) using GPD-GED-ICP-MS

◆ Geological

- Laser ablation ICP-MS technique is commonly used for determination of elemental analysis. However, a sample piece needs to be placed in a small chamber and a mixture of Ar and He gas carries ablated particles into ICP-MS.
- *GED* doesn't require such a small chamber, and any size and shape of sample in atmosphere can be analyzed as shown in Fig.7.
- *GED* can improve Pb isotope ratio measurement by removing Hg vapor that causes polyatomic interference on Pb.

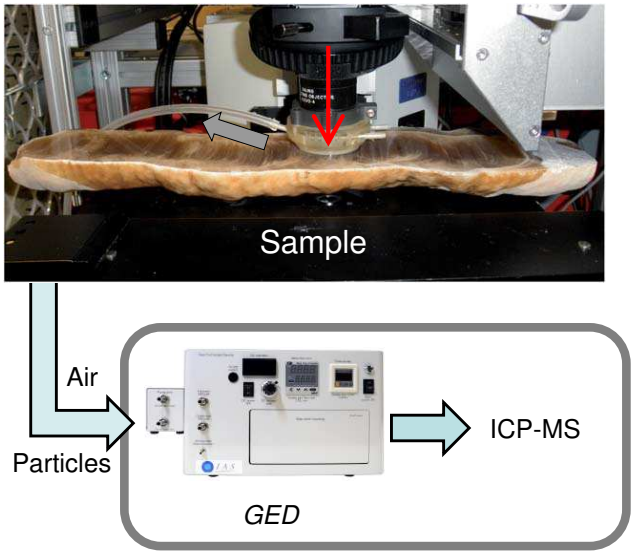


Fig.7 Direct solid sample analysis by LA-GED-ICP-MS

◆ Tobacco

- Tobacco smoke was analyzed as shown in Fig.8 and 9. Sidestream smoke showed significant amount of Cd and Tl (red), while mainstream smoke showed much less amount of these elements (blue), which indicated that some Cd was trapped by the filter, but the remaining Cd might be aspirated by a smoker. On the other hand, more Pb was detected from the mainstream, which may come from the filter.

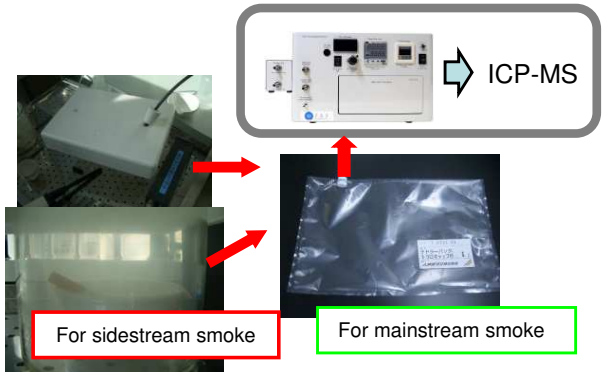


Fig.8 Analysis of tobacco smoke

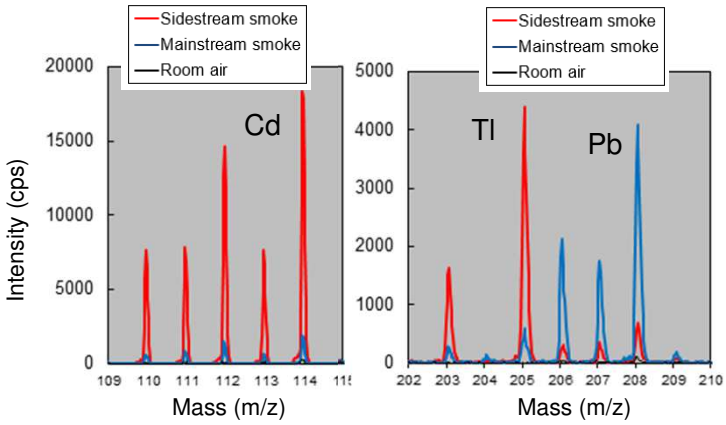


Fig.9 Spectra of tobacco smoke analysis

◆ Exhaust gas from cars

- Pt and Rh were detected from car exhaust as shown in Fig.10, which may come from catalysts used for exhaust emission control.

◆ Combination with particle counters

- SMPS (Scanning Mobility Particle Sizer) can measure particle distribution in air using ^{241}Am neutralizer, but it doesn't work properly in other gases used in semiconductor industry such as H_2. The *GED* can be used to exchange gases with air, which enables precise measurement of particle distribution in various gases.

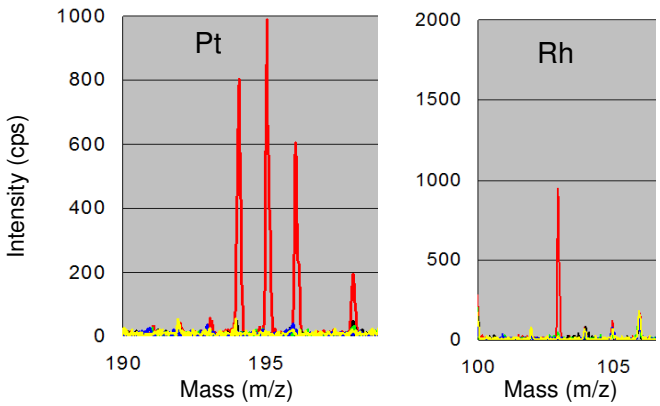


Fig.10 Spectra of car exhaust analysis

◆ Line up of GED products

GED Units

GED_SEMI **model for Semiconductor Special Gases**

GED_Q **model of Higher flow model**

GED **model of lower flow model**

GPD **(Gas Particulation Device)**

MSAG **(Metal Standard Aerosol Generation Device)**

IAS Inc.
2-2-1 Hinohonmachi, Hino, Tokyo, 191-0011 Japan
TEL: +81-42-589-5525
E-Mail: iasjapan@iasinc.jp URL: https://iasinc.jp

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