# Metal ceramic components for space applications

**In recent years the Applied Technology and Development Group (GVE) has developed and produced various ion optical components for the three sensors of the so called ROSINA module, which is under the responsibility of the University of Bern. This instrument group is part of the ESA space science programm ROSETTA, whose probe will be launched in January 2003 and will meet the comet Wirtanen eight years later. Development work focused on technologies for joining components made of exotic metals like titanium, molybdenum and niobium as well as ceramics, whereby ultra-high vacuum tightness, high voltage strength and geometric accuracy (in some cases the allowed deviations were less than 0.02 mm) had to be guaranteed without impacting the strict lightweight and strength requirements.**

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Due to small physical dimensions and low weight, one of these sensors is a reflectron type time-of-flight (RTOF) mass spectrometer. The use of two reflectors multiplies the measurement (flight) path length inside

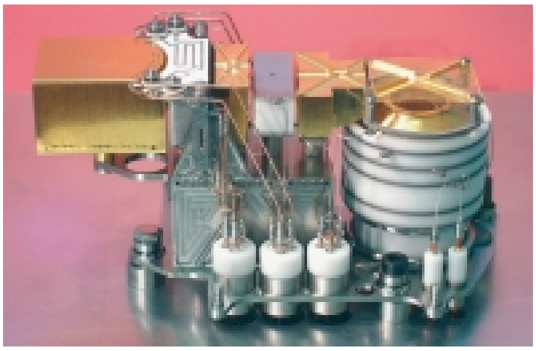

***Fig. 1:*** *"Orthogonal source" ion source for measuring ionised gases (flight model/length: 97 mm).*

a relatively short vacuum enclosure. The resulting RTOF mass spectrometer has an overall length of about 1 m but is capable of analysing and separating light to moderately heavy molecules in the range of 1–300 amu (atomic mass unit): it is possible to clearly resolve nitrogen ($N_2$) and carbon monoxide (CO), despite a difference in the mass of the two molecules of only approx. $^{1}/_{3000}$.

GVE has developed and built both ion sources, the two reflectors (integrated reflectron and hard mirror) and some further electric components (e.g. high voltage and coaxial connectors) for this scientific instrument.

Several parts of each module are made of aluminium oxide ceramic, mainly required for its dielectric properties. In order to join the ceramic with the metallic counterparts, brazing and high temperature brazing technologies have been selected, enabling strong

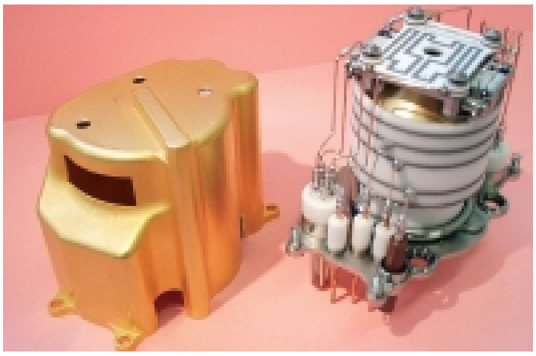

***Fig. 2:*** *"Storage source" ion source for measuring non-ionised gases (flight model).*

and ultra-high vacuum tight modules. The sophisticated engineering required the high precision brazing of complex assemblies (in some cases up to 20 parts at one time), which could only be carried out by using customized jigs. A major feature of these jigs is their thermal expansion and capacity, which had to be matched to the brazed assemblies. Furthermore, since the produced components were extremely delicate, the design of the jigs had to allow a secure handling, especially during the disassembly procedure.

The ion source main structure is a high precision brazed and welded construction consisting of a stack of gold plated concentric metal electrodes and insulating ceramic rings. The geometric tolerances are less than 0.02 mm, while the high voltage strength of some insulators reaches –6000 V.

An integrated 10 W heating element allows the ion box of each source to be baked out for calibration and cleaning. The heating element was screen printed on a ceramic substrate and since the thermal output has to be accurately monitored, a thin film Pt1000 type temperature sensor was integrated in the brazed metal-ceramic construction.

Using two reflectors makes the instrument more compact without impairing the resolution. Electrical fields produced by concentric electrodes are used to decelerate and reaccelerate the ion beam in the opposite direction.

In order to achieve the weight requirements, the single components of the integrated reflectron have to fulfil both structural and functional tasks: the reflectron is part of the spectrometer vacuum enclosure

***Fig. 3:*** *Integrated reflectron: highly vacuum-tight titanium/ceramic compound (flight spare/length: 267 mm).*

and has to withstand the mechanical loads during launch, while its internal surface generates the necessary electrostatic fields.

***Fig. 4:*** *Hard mirror – a simplified version of the integrated reflectron (top and bottom/length: 87 mm).*

Since in two sectors the field has to show a gradient, helix-shaped resistor tracks of 15 m total length and an overall resistance of 1.5 GΩ were applied on the inner ceramic surface with a CNC dispenser. The limited weight and the high voltages applied required the use of titanium and its alloys as well as alumina ceramic, which had to be joined by brazing. The extremely high reactivity of titanium and the poor wettability of the ceramic surfaces required the development of a new brazing process, whereby the surface treatments play a very important role. The brazed sub-assemblies were joined together by electron beam and laser welding. This led to the production of reliable lightweight components, which passed a 7-day-long vacuum-keeping test (pressure at the end of test: $p < 1 \cdot 10^{-7}$ mbar) and this after the prescribed vibration test.

The hard mirror is a simplified and miniaturised version of the integrated reflectron. It is a brazed and welded construction, and the used materials are mainly titanium and alumina ceramic. Because of the very small volume available, most of the electrodes were produced by partial metalization of a conically shaped ceramic tube.

Further development on the time-of-flight mass spectrometer is planed for a mobile unit, as the most striking feature is its small size, wich could easily be used for on-site measurements, for example. The regular time delay would not apply, and a modification of the sample collection could instantly be carried out. A mobile unit could also support scientific fields such as atmospheric air pollution. Such use is facilitated by its low weight (~15–20 kg), diameter of 0.25 m and length of 1.2 m. The resolution remains at $^{1}/_{2500}$ – $^{1}/_{3000}$ amu, which means that it is straightforwardly possible to resolve CO from $N_2$. A new, more flexible and even lower cost production method has now been conceived for the current components, which could be tailored and integrated into existing designs, as well.

**Links:** www.sci.esa.int/rosetta
www.phim.unibe.ch/rosina/rosina.html

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