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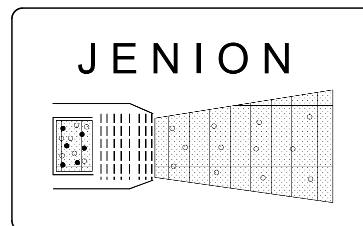

Material Technology by New Plasma- and Ion Beam Techniques

Ion Source JENION ACC-40 IS

1 Application

The compact Broad Ion Beam Source JENION ACC-40 IS generates an ion beam for applications in the fields of:

- **Ion Beam Sputtering for thin film deposition,**
- **Nano technology, ion beam nanoscale surface modification, ion beam controlled textured film growth, crystal growth,**
- **Ion Beam Assisted Deposition (IBAD) with noble gases and with oxygen (oxides), nitrogen (nitrides), or with hydrocarbons (carbides, diamond like carbon),**
- **Reactive Ion Beam Etching (RIBE) with oxygen (polymers) or fluorocarbons (semiconductors, quartz glass),**
- **Helium and hydrogen ion source for basic research,**
- **Bio-medical surface preparation with molecular ions,**

in a wide ion energy range from 50 to 1000 eV.

This one flange or inline system with a computer controlled electronic control unit is a compact and cost effective solution for all fields in research and development requiring a broad ion beam with 40 mm diameter. Because of its good linearity in ion beam profile control it also can be used in industry for local sputtering or ion beam planarization.

2 JENION ACC-40 IS

The ion source ACC-40 IS is primarily developed for research and development. Compared to other 40 mm ion sources, which deliver up to 50 mA ion beam current, our ion source is designed for ion currents of some tenths of mA but with a lot of different precursors from a cost effective and compact ion source.

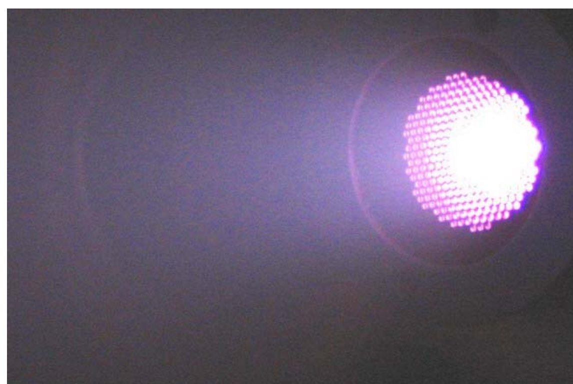

Fig.1: Ion source JENION ACC-40 IS (left), and in operation

2.1 Principle

In contrary to a hot cathode plasma the ion source ACC-40 IS (Fig.3) generates the ion source plasma without a hot and plasmachemically unstable filament by a magnetic field induced cold cathode discharge at nearly 50 kHz using the patented arrangement of two so called "Alternating Cathodes" [1].

The ion beam is extracted by a two grid graphite extraction system. A filament neutralizer can be used to neutralise the ion beam.

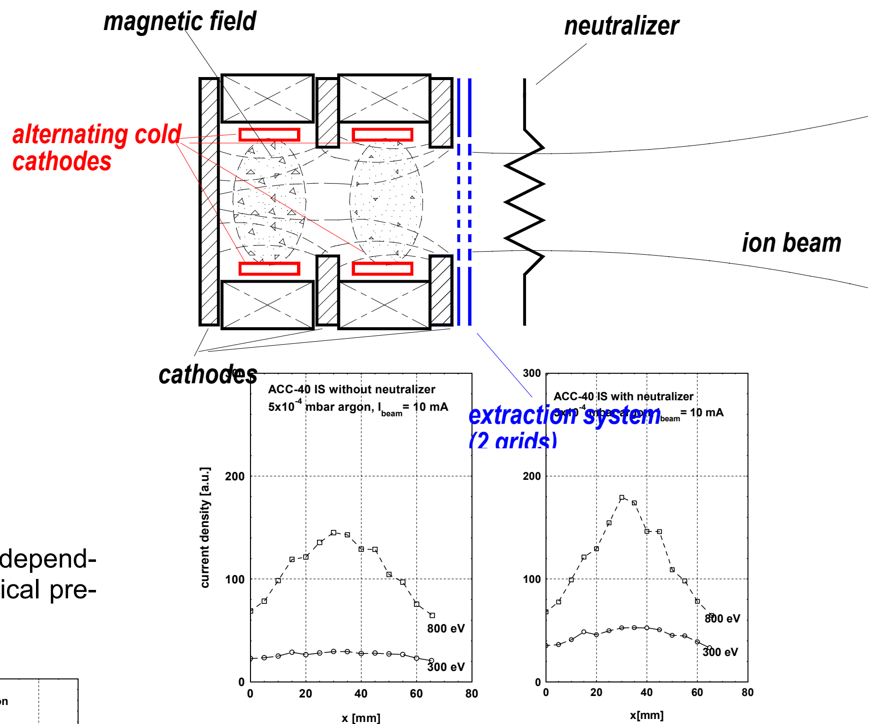

Fig.4 shows the ion beam current in dependence of the beam energy for some typical precursors.

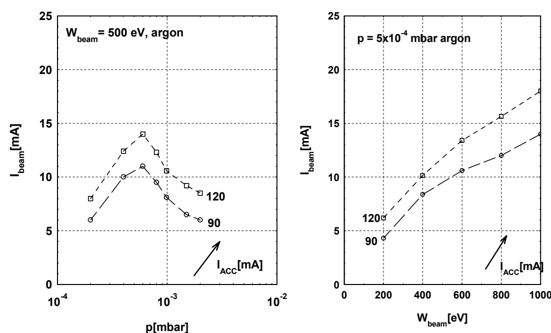

Fig.4: Ion current (I_beam) in dependence from the pressure and from the ion energy (U_accel = 60 V, no neutralizer)

The ion beam profile has in general a gaussian shape, which is sparsely dependent on the ion energy and the space charge neutralisation at higher ion currents or at ion energies lower 200 eV (fig.5).

Fig.5: Ion beam profile without and with ion beam neutralization (ACC-40 IS, $5x10^{-4}$mbar, argon)

Fig.3: Principle of the Alternating Cold Cathode Ion source ACC-40 IS

The 50 kHz-generator of the ACC-ion source normally generates a rectangular pulse with 50% on-cycle. For special purposes like ion beam planarization of glass or silicon a very fine controllable ion beam with a constant ion beam profile is required. For this the pulsed

mode of the ACC-ion source can be used by controlling the ion beam by the puls ratio of the ACC-generator which can be shifted from < 5% to 50% on-cycle. Fig.6 shows that by this way a constant ion beam profile can be generated over a wide ion beam range.

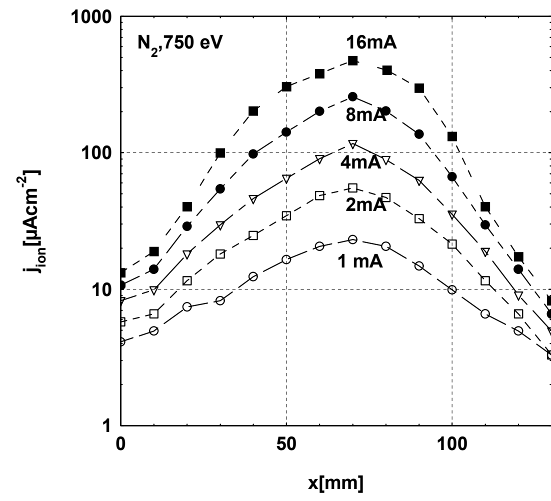

Fig.6: Ion beam profile linearity at 150 mm distance for ion beam currents from 1 to 16 mA regulated by discharge pulsing

2.2 Technical Data

Tab.1 shows the technical data of the ion sources.

	JENION ACC-40 IS
ion beam diameter [mm]	40
vacuum flange	CF 100 or inline mounted
dimensions	95 mm diameter 170 – 200 mm length (depending on neutralizer and mounting
ion energy [eV]	20 - 1000
ion current density [mAcm^{-2}]	0.1-2
ion beam [mA]	1- 25
discharge type	alternating cold cathode ion source
discharge voltage [V]	400 - 600
discharge current [mA]	25 - 125
neutralizer	filament
grid system	2 grid system
gas input [sccm]	2 - 10
impurities (% of ion beam current density)	0.1 - 1

Tab.1: Technical data of the broad ion beam source ACC-40 IS

3 Components of the System

The ion beam sources consist of a flange mounted or internal mounted ion source, a computer controlled Electronic Control Unit, the control software and some optional components like shown at fig.7.

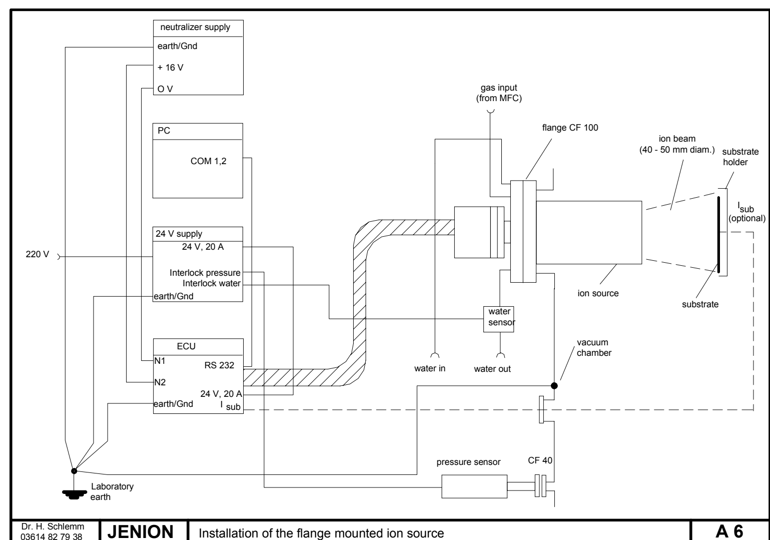

Fig.7: Overview of the ion source installation

3.1 Ion Beam System

- The ion source consists of the following components:
- Alternating Cold Cathode ion source (ACC-40 IS),
- Separate 2 grid ion extraction system (can be removed for discharge chamber cleaning),
- Compact ion source (length 200 mm) with integrated water cooling mounted on CF 100 flange (flange mounted), or compact ion source for internal mounting with internal cable connector (<100 cm) and 6 mm Swagelock connectors for water cooling,

3.2 Electronics and Power Supplies

- Compact processor controlled Electronic Control Unit powered by an separate 24 V power supply containing all required interlocks for safe ion source operation (see Fig.9, 10 and 11),
- Connected to the PC by RS 232-interface.

3.3. Software

Fig.8 shows a screenshot of the software.

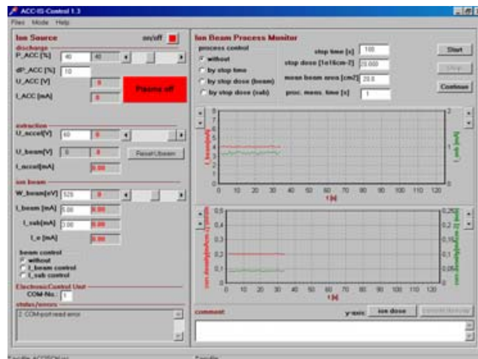

Fig.8: Screenshot of the Ion source Control software for ACC-ion sources

The software operating under WIN9x, WINNT, WIN 2000 and WIN XP controls all functions of the ion sources like:

- Ion source discharge (ACC-discharge, plasma ignition),
- Ion beam extraction (ion energy, extraction voltages for screen- and acceleratorgrid),
- Ion beam data (ion energy, total ion beam from the ion source, ion beam at the substrate, ion beam from the filament neutralizer (optional).
- Ion beam regulation (regulation of the total ion beam or the substrate ion beam to a setpoint value).

The integrated “ion beam process monitor“ can be used for analyzing the generated ion beam or for process control by:

- Observing ion beam current, ion beam dose or ion beam density over a given process time,
- Process stopping after a programmed time, or after a programmed ion dose.

All parameters for operation of the system are loaded and saved by files ("settings"). All results of the ion beam process monitor can be saved as ASCII-files for further documentation.

The software contains an extended integrated help system. Additional a manual is delivered, describing the system, its theory and function and some application examples from all kinds of applications.

Fig.9: Electronic Control Unit

Fig.10: Electronic Control unit (back side with ion source connector cable)

Fig.11: Optional Interlock- and main power interface

3.4 Optional Components

- Filament neutralizer supplied from an external DC-power supply
- Ion beam profile analyzer by a line of faraday-cup arrays (see [2]).
- Substrate holder with linear substrate motion, stepper motor driven [7],.
- Vacuum-Interlock- and main power adapter for safe ion source operation (if not realized by the control system of the vacuum equipment, see fig.11), [8]
- Ion source heater for ion source temperatures up to 300 C (e.g. for use with liquid or solid precursors like some monomers or low temperature melting metals like indium, selen plumbum or tin). [9]

4 Application Examples

Tab.2 gives an overview about the precursors usuable in the ion sources.

Precursor type	Precursors	remarks
noble gases:	He, Ne, Ar, Kr	Graphite grids, long term stable
permanent gases.	H_2, N_2, $\mathbf{O_2}$	For O_2 stainless steel grids
hydrocarbons:	CH_4, C_2H_2, ... (graphite deposition at the ion source, removing by oxygen plasma)	Discharge chamber cleaning after some hours required
fluorocarbons:	CF_4, C_2F_6,.... (graphite deposition at the ion source, removing by oxygen plasma)	
chlorocarbons:	CCl_4, C_2CL_6,... (graphite deposition at the ion source, removing by oxygen plasma)	
water, alcohol e.t.c.	H_20, C_2H_5OH,	
halogens:	Cl_2, HCL	
Liquid monomers	> C_8H_x.....	Together with the ion source heater [9]
Low temperature melting metals	Sn, Zn, Pb, ...	Together with the ion source heater [9]

Tab.2: Usuable precursors for the ion sources ACC-40 IS

The ion source is well suited for noble gases like argon or krypton and for hydrogen and nitrogen. Hydrocarbons and fluorocarbons also can be used, but after operating times of some hours there grows a graphite layer in the ion source, which has to be cleaned up mechanically.
The big advantage of the ACC-ion source is its oxygen-stability. This opens up the possibility to use a lot of carbon based molecular gases and to remove their deposited graphite at the ion source by plasma etching with oxygen.

4.1 Ion Beam Assisted Deposition (IBAD)

- IBAD with argon for ion implant induced thin layer formation,
- IBAD with oxygen for oxide layer formation,
- IBAD with nitrogen for nitride layer formation,

4.2 Reactive Ion Beam Etching (RIBE)

The ion source ACC-40 IS can be excellent used for reactive ion beam etching for:

- Anisotropic etching of SiO_2 with CF_4 + 20 % O_2 at 500 - 1000 eV,
- reactive etching of silicon with CF_4 at 300 eV.

Like shown at Fig.12 etch rates up to 0.8 µm/min can be achieved at quartz glass.

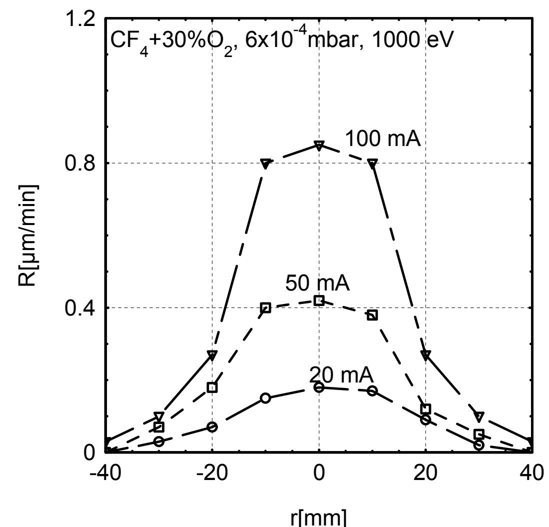

Fig.12: RIBE-etchprofiles at quartz glass for discharge currents (I_ACC) from 20 to 100 mA

4.3 Bio-Medical Surface Preparation

- Surface modification of bio-medical surfaces with functional groups for generation of selected areas of different biocompatibility,

4.4 Direct Ion Beam Deposition

- Direct ion beam deposition of diamond like carbon from ion beams for unsaturated hydrogencarbons like C_2H_2 or C_2H_4 ,

4.5 Ion Implantation

- Basic investigations with broad ion beam implantation up to 60 keV ion energy (see [6]).,

5 Options and Modifications

Beside the flange mounted 40 mm ion sources which is thought to be a more universal device for research and development with cost effective ion beams, other customer specified solutions are possible. These could be:

- Linear ion sources basing on the ACC principle up to dimensions of 600 mm length,
- Customer spezified ion beam dimensions,
- Pulsed ion beams,
- Faraday-cup array control of the ion beam current density [2],
- Customer specified arrangement of the ion source at the vacuum chamber (inline, moved e.g. on a x-y stage),
- High energy broad beam ion implantation up to 60 keV (see " Broad Beam Ion Implantation with linear ACC ion sources JENION ACC-30x150 IMP, ACC-40 x300 IMP and ACC-40x600 IMP " [6]),
- Customer specified ion sources for broad ion beams for ion energies from 1 to 10 keV,
- Heated ion source for liqueous precursors and low temperature melting metals [9].

6 References

[1] H. Schlemm, H. Neumann, Deutsches Patent, DE 199 28 053 A1 (1999).

[2] “PlasmaMon – plasma probe measurement for plasma and ion beam analysis“, product information JENION 2002.

[3] "Mass Separated Ion Source JENION K-40 MIS", product information, JENION 2000.

[4] I.G. Brown, "The Physics and Technology of Ion Sources", J. Wiley & Sons, New York 1989.

[5] J.J. Cuomo, S. M. Rossnagel, H. Kaufman, "Handbook of Ion Beam Processing Technology", Noyes Publications, Park Ridge 1989.

[6] "Broad Beam Ion Implantation with linear ACC ion sources JENION ACC-30x150 IMP, ACC-40 x300 IMP and ACC-40x600 IMP " product information, JENION 2003.

[7] “Linear substrate holders for plasma- and ion beam processing”, product information JENION 2003.

[8] “Vacuum-interlock unit”, product information JENION 2003.

[9] “Ion source heaters”, product information JENION 2003.