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JENION

Material Technology by New Plasma- and Ion Beam Techniques

Linear Broad Beam Ion Sources

ACC-30x150 IS, ACC-40x300 IS and ACC-40 x 600 IS

1 Application

The compact linear broad ion beam sources basing on the ACC-principle generate 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 or 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 sources for basic research,**
- **Bio-medical surface preparation with molecular ions,**
- **Broad Beam Ion Implantation with ion energies up to 60 keV with noble gases or with oxygen, nitrogen or hydrocarbons (stoechiometric formation of implanted oxides, nitrides or carbides).**

The ion sources generate a homogeneous linear ion beam at a wide ion energy range from 50 to more than 1000 eV. Together with a linear substrate transport mechanism ion beam processes can be carried out with accurate homogeneity and high productivity.

Fig.1: Ion Source JENION ACC-30x125 IS

The ion sources are inline mounted and equipped with a computer controlled electronic control unit as a compact and cost effective solution for all fields in industrial use and in research and development requiring a linear broad ion beam.

The ion sources are filamentless and operate with nearly all kinds of gases and also (heated versions up to 300 C) with metal vapours of low temperature melting metals.

Fig.1 shows a typical linear ion source. Fig 2 shows it in operation with oxygen and hydrogen.

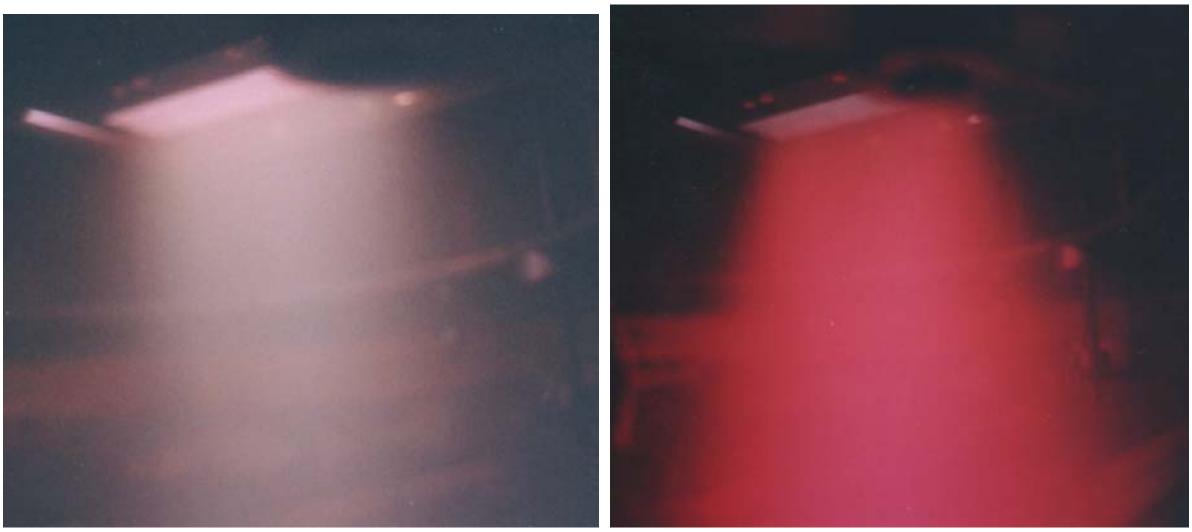

Fig.2: Ion source JENION ACC-30x125 IS in operation with oxygen (left) and hydrogen (right)

2 Linear ACC-Ion Sources

Broad beam ion sources can be used in a wide field of thin film technologies ([4,5]). Linear ACC-ion sources can be used both for industrial thin film technologies and for research and development. Compared to other linear ion sources, which deliver up to 2.0 mA ion beam current density, our ion sources is designed for ion current densities between 0.3 and 1.5 $mAcm^{-2}$ but operate with a lot of different precursors from a cost effective and compact ion source.

2.1 Principle

In contrary to a hot cathode plasma the ACC-ion source (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 extraction system. A filament or plasma bridge neutralizer can be used to neutralise the ion beam.

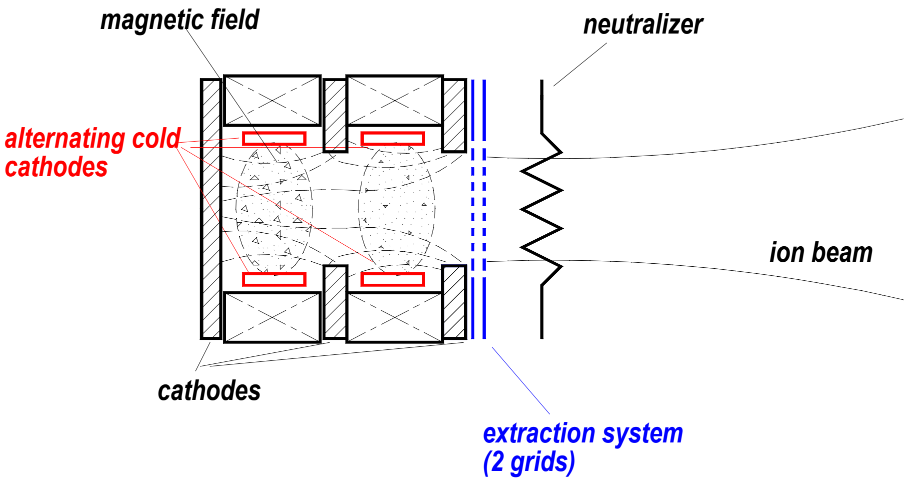

Fig.3: Principle of the Alternating Cold Cathode Ion source

Fig.4 shows the ion beam current density in dependence of the pressure. A typical process pressure for ACC-ion sources is between 4 and $6x10^{-4}$ mbar (depending on the pump speed of the high vacuum pump).

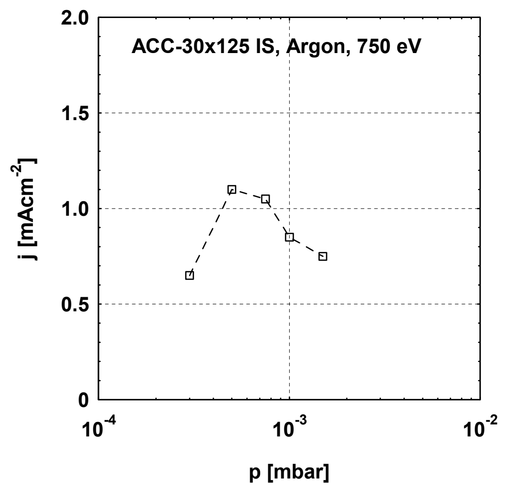

Fig.4: Ion current density in dependence from the pressure

Fig.5 shows the influence of the beam voltage on the ion current density at a fixed accelerator voltage of – 60 V.

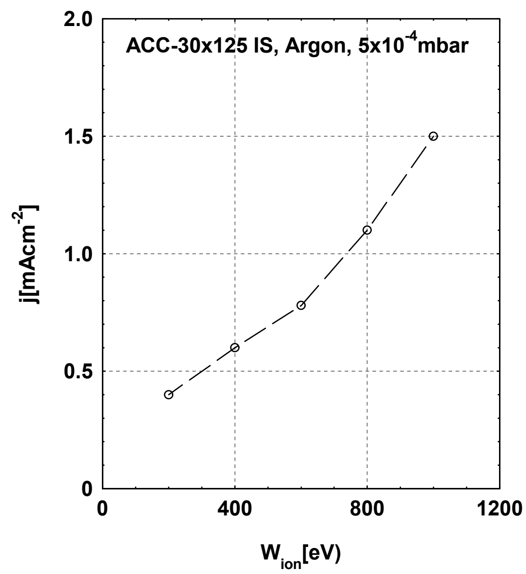

Fig.5: Ion current density in dependence from the ion energy (fixed accelerator grid voltage of – 60 V).

The ion beam homogeneity along the length of the ion beam is important for use in linear thin film processing by ion beams is.

Fig.6. shows the ion current density profiles for the three types of linear ion sources. Detailed data of the usable ion beam dimensions are shown at tab.1.

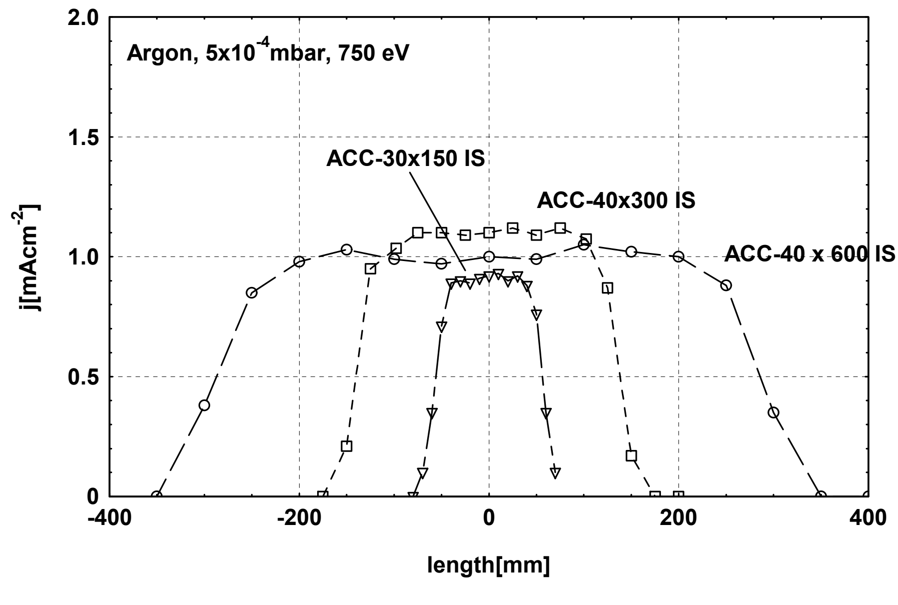

Fig.6: Ion beam profiles for linear ACC-ion sources with 125mm, 250mm and 500 mm length.

2.2 Technical Data

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

Property	ACC-30x150 IS	ACC-40x300 IS	ACC-40x600 IS
dimensions (length x width x hight) [mm]	200 x 100 x 190	350 x 100 x 190	650 x 100 x 190
Ion beam width (at 100 mm distance)	40 mm	60 mm	60 mm
ion beam length (at 100 mm distance)	150 mm	300 mm	600 mm
homogeneous ion beam length (at 100 mm distance, < 5%)	75 – 100 mm	200 – 250 mm	450 – 500 mm
vacuum flange	Inline mounted (optional ISO 250, CF 250)	Inline mounted	Inline mounted
ion energy [eV]	50 – 1000 eV	50 – 1000 eV	50 – 1000 eV
ion current density [mAcm^{-2}]	0.1 - 1.5	0.1 - 1.5	0.1 - 1.5
ion beam	5 – 50 mA	10 – 100 mA	20 – 250 mA
discharge voltage	500 – 900 V	500 – 900 V	500 – 900 V
discharge current	25 – 150 mA	50 – 300 mA	100 – 500 mA
Neutralizer	Optional filament or plasma bridge	Optional filament or plasma bridge	Optional filament or plasma bridge
grid system	2 grid system from graphite (optional stain-less steel, titanium, tung-sten)	2 grid system from graphite (optional stainless steel, titanium, tungsten)	2 grid system from graphite (optional stainless steel, titanium, tungsten)
gas input	3 – 15 sccm	5 – 25 sccm	10 – 50 sccm
impurities (% of ion beam cur-rent density)	0.03 - 1	0.03 – 1	0.03 - 1
Cooling water flow	Optional (1-3 l/min)	1-3 l/min	2-5 l/min

Tab.1: Technical data of the linear broad ion beam sources

3 Components of the System

Ion beam sources consist of a inline mounted ion source (optional flange mounted possible), a computer controlled Electronic Control Unit (ECU), the control software installed at a separate PC and some optional components. Fig.7. shows the installation in an overview.

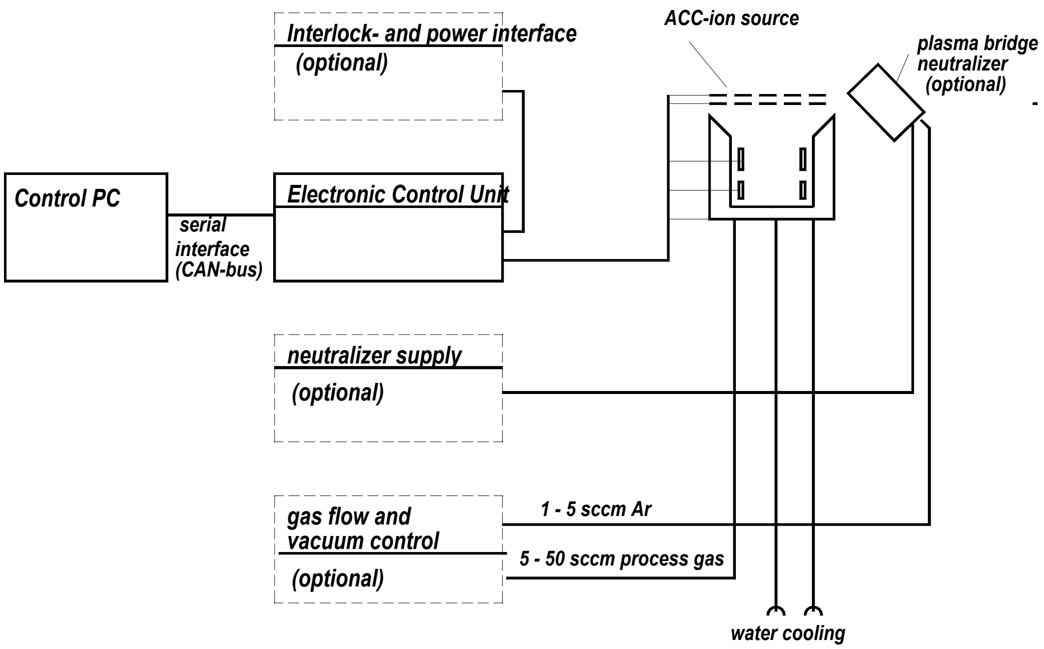

Fig.7: Overview of the ion source installation

3.1 Ion Beam System

Linear ACC-ion source consists of the following components:

- Linear Alternating Cold Cathode discharge plasma chamber with permanent magnets,
- Separate 2 grid ion extraction system (can be removed for discharge chamber cleaning),
- Compact ion source (width 100 mm) with integrated water cooling mounted on an internal holder, with internal electrical cable and 6 mm Swagelock connectors for water cooling and gas supply,

Fig.8: Electronic Control Unit (front side)

Fig.9: Electronic Control unit (back side with ion source connector cable)

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.10),
- connected to the PC by RS 232-interface.

Fig.8 and fig.9 show the Electronic Control Unit.

Fig.10: Optional Interlock- and main power interface

3.3. Software

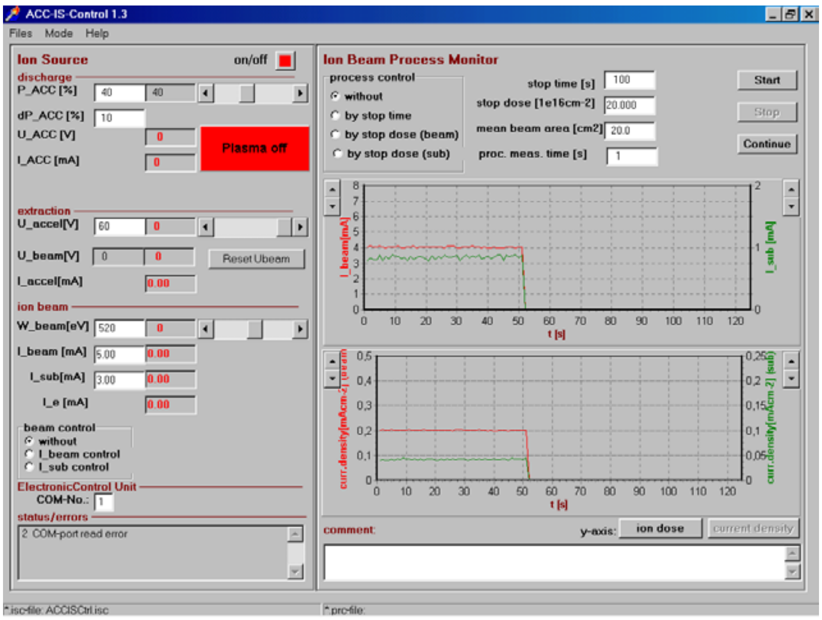

Fig.11: Screenshot of the Ion source Control software for ACC-ion sources

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.

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), [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

ACC-ion sources are 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 the possibility to use a lot of carbon based molecular gases and to remove their deposited graphite inside the discharge chamber by plasma etching with oxygen.

4.1. Sputtering

- Use for direct ion beam sputtering from linear targets for metal semiconductorand oxide layer systems (especially because of the oxide stability of the ion source additional oxygen for stoechiometry control of sputtered oxide layers can be used),

- Sputter deposition of nanoscale layer systems (ACC-ion sources can very precise switched on and off (start time < 300 ms).

4.2. Nano technology and crystal growth

- Ion beam nanoscale surface modification,
- Ion beam controlled textured growth,
- Crystal growth.

4.3 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,
- IBAD with hydrocarbons for carbide layer formation.

4.4 Reactive Ion Beam Etching (RIBE)

- 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,

4.5 Bio-Medical Surface Preparation

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

4.6 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 ,

4.8 Ion Implantation

- Ion implantation up to ion energies of 50 keV for stoechiometric thin film implantation of oxide- nitride or carbide layers,
- Ion implantation for hardness increase at machine tools,

5 Options and Modifications

For research and development also a small ACC-ion source with 40 mm ion beam diameter is available ([3]).
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 at the basis of ACC-ion sources are possible. These could be:

- 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 50 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 spezified ion sources for broad ion beams for ion energies from 1 to 10 keV.

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] ”Alternating Cold Cathode Ion source JENION ACC-40 IS”, product information , JENION 2003.
[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 Publ., 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.