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JENION

Material Technology by New Plasma- and Ion Beam Techniques

Application Note

Ion Assisted Deposition of Optical Layers with JENION ACC- Plasma Sources

1 Introduction

Optical and ceramic oxide layers can be deposited by reactive or non-reactive magnetron sputtering of oxide targets or by evaporation of oxides or pure metals in conjunction with an oxygen plasma generated by plasma source. The ion current and the oxygen radical stream (O_x) of the chamber plasma is large enough to enable oxide deposition at rates of 1 - 5 nm/s like common delivered from electron beam evaporators. Fig.1 shows the principle of IAD.
Three important layer features are controlled by the plasma source:

- Oxygen radicals and oxygen ions from the plasma shift the stoechiometric composition of the deposited oxide layer, resulting in control of the optical properties of the layer (refractive index, optical absorption, thickness),
- The plasma enables a reduced deposition temperature (important for optical layers at polymer lenses e.t.c.)
- The deposited layer have a higher density and a more compact structure because of ion bombardment.

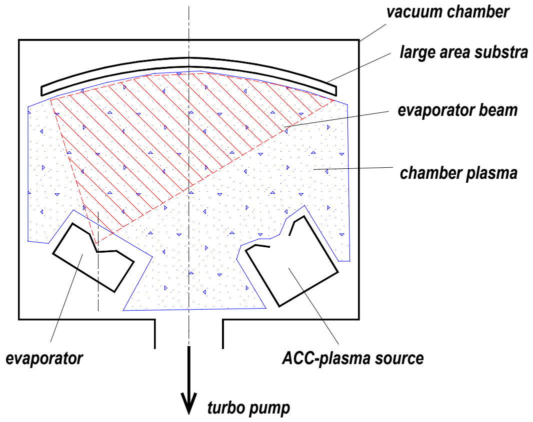

Fig. 1: Principle of Ion Assisted Deposition

In principle both Broad Beam Ion Sources and Plasma Sources generating plasmas with remarkable ion energies at pressures below 5×10^{-4} mbar can be used. Tab.1 shows the differences between application of plasma source and broad beam ion sources.

JENION manufactures both Plasma Sources and Ion Beam Sources. For IBAD with JENION Ion Sources see [1,2] and [3].

	Ion Assisted Deposition (IAD)	**Ion Beam Assisted Deposition (IBAD)**
Ion energy range	10 – 100 eV	100 – 1000 eV
type of source	Plasma source	Broad beam ion source
Layer deposition influenced by:	All generated plasma species (excited neutrals, ions, electrons)	ions
Typ. growth rates	10 – 300 nm/min	10 – 100 nm/min
Typ. atom/ion ratio	10 - 1000	$100 - 10^4$
Typical applications	IAD of optical coatings with defined optical parameters	IBAD of metal, semiconductor or isolating layers with defined compact structure and reduced inner stress

Tab.1: Parameter ranges for Ion Assisted Deposition (IAD) and Ion Beam Assisted Deposition (IBAD)

2. Ion Assisted Deposition (IAD) with ACC-Plasma sources

Fig. 2 shows the principle of the patented [6] Plasma Source. Between three cathodes two further electrodes are arranged powered by a radio-frequency generator (50 kHz). It switches these electrodes between cathode and anode potential so that they act altering as cathodes or anodes at a cold cathode gas discharge. Because of the radio-frequency plasma generation isolating layers on the electrodes do not influence the discharge (like at dc-cold cathode discharges).

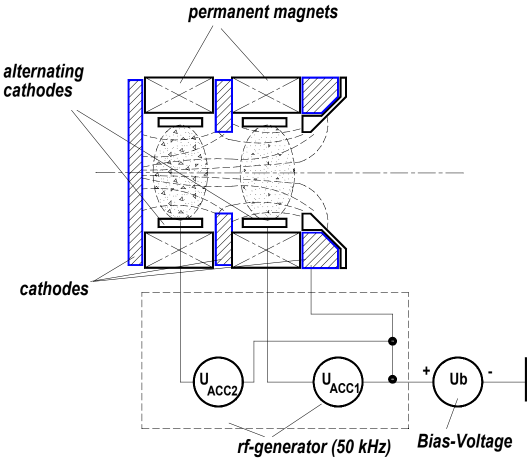

Fig. 2: Principle of a alternating cold cathode plasma source

If the bias voltage shown at Fig.2 is close to zero a quasi neutral plasma stream with ions at energies lower than 20 eV is generated by the plasma source. If the bias voltage is increased up to + 300 V more and more ions with energies up to 100 eV leave the plasma source. To avoid a positive charging of isolated substrates like glass lenses e.t.c. the plasma now has to be neutralized. This can be done by two ways:

a) **filament neutralizer**:
A tungsten filament in front of the plasma source generates an electron flux neutralizing the excess charge of positive ions and keeping the plasma potential close to ground. This is a simple and good method for neutralizing but only works at oxygen plasma some hours because of the oxidation of the filament.

b) plasma bridge neutralizer:
The plasma bridge neutralizer (like shown at fig.3) is an electron gun delivering low energy electron currents up to some amps at electron energies of 10 – 30 eV to the plasma for neutralizing. Inside the neutralizer an argon DC-discharge is ignited. An additional gas flow of some sccm argon comes from this type of neutralizer to the process chamber.

By using the plasma bridge neutralizer no hot filaments are placed into the oxygen plasma and long term operation until 100 h will be achieved.

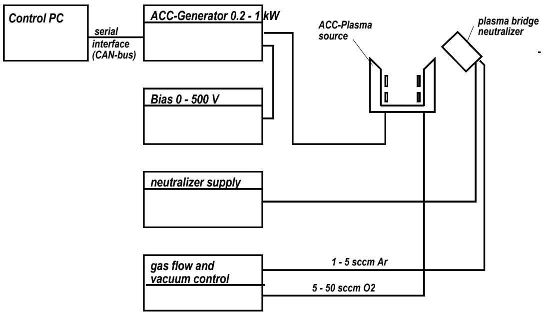

Fig. 3: ACC-Plasma source in a filamentless configuration together with a plasma bridge neutralizer

The plasma source configuration for IAD is shown at fig.3. It contains the following parts:

a) ACC-plasma source:

Inline mounted plasma source with electrical feedthrough from the ACC-generator and feedtroughs for cooling water an gas.

b) Plasmabridge neutralizer:

Inline mounted near the plasma source with separate electrical and gas feedthrough.

c) ACC-generator with control PC:

PC controlled low frequency generator (50 kHz, 500 W) for cold cathode plasma generation inside the plasma source connected to the bias and the neutralizer supply.

d) DC bias supply:

PC controlled bias voltage (0 to 500 V, < 1A).

e) Neutralizer supply:

Special electron source supply for plasma bridge neutralizers.

f) Gas flow and vacuum control (optional if not already part of the vacuum equipment).

3. Typical technical data

Beside the ACC-plasma sources of 40 and 80 mm diameter also rectangular (linear) dimensions are available. Tab.1 gives an overview about the properties of this sources.

	JENION ACC-40 PS	**JENION ACC-80 PS**	**JENION ACC-30 x 150 PS**
Typical application	IAD for research	Industrial IAD	Special linear plasma sources for industrial use
Plasma source dimensions	100 mm diameter x 180 mm	130 mm diameter x 180 mm	200 x 100 x 190 mm
Output dimensions	40 mm diameter	80 mm diameter	30 x 150 mm
Output plasma current	10 – 100 mA	0.1 - 0.5 A	0.1 - 0.5 A
Discharge current	10 – 100 mA	0.1 - 0.5 A	0.1 - 0.5 A
Discharge voltage	350 - 800 V_s	350 - 800 V_s	350 – 800 V_s
Bias Voltage	0 V to 400 V	0 V to 400 V	0 V to 400 V
ion current density near field plasma [mAcm^{-2}]	0.1 to 1	0.1 to 1	0.1 to 1
ion current density chamber plasma [µAcm^{-2}]	10 to 50	10 to 50	10 to 50
ion energy [eV]	30 - 150	30 - 150	30 - 150
impurities	0.05 to 1 % of the plasma current	0.05 to 1 % of the plasma current	0.05 to 1 % of the plasma current
gas flow [sccm]	5 - 30 (Ar)	10 - 100 (Ar)	10 - 100 (Ar) 11
water flow for cooling [l/min]	(1 – 5) only for long term use	1 - 5	1 – 5

Tab.1: Technical data of the JENION ACC-plasma sources

References

[1] “Broad beam ion source JENION ACC 40 IS”, product information, JENION 2003.

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

[3] “Ion Beam Assisted Deposition (IBAD) with the broad beam ion sources JENION ACC-40 IS and ACC-30 x 150 IS”, application note, JENION 2003.

[4] “Plasma sources JENION ACC 40 PS and ACC 80 PS”, product information, JENION 2003.

[5] H.J. Niederwald, N. Kaiser, U.B. Schallenberg, A. Duparre, D. Ristau, M. Kennedy, “ IAD of oxide coatings at low temperature: a comparison of process based on different ion sources”, SPIE Vol. 3133, 205.

[6] “Linear broad beam ion sources ACC-30x150 IS, ACC-40x300 IS and ACC-40x600 IS”, product information JENION 2003.