CEITEC NANO
Research Infrastructure
BRNO | CZECH REPUBLIC

Etching & Deposition

Ion beam etching Scia Systems Coat 200

DESCRIPTION

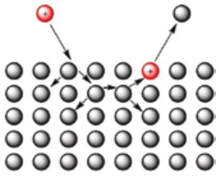
Ion beam etching (IBE) removes material from the etch target by bombardment with directed and precisely controlled ion energies. IBE is also referred to as "ion beam milling". The IBE source generates plasma from a noble gas, typically argon. A set of electrically biased grids establish the ion beam energy and angular divergence of ions within the beam. The ion beam strikes the substrate, removing material by physical sputtering.

Ion beam etching provides directional flexibility that is not available in other plasma processes. While the etch rate with IBE is typically lower than for reactive ion etching (RIE), IBE offers high precision (high anisotropism) for applications that demand exacting profile control. Also, ion beam etching can be used to remove materials where RIE may not be successful. Ion beam can etch alloys and composite materials that are not compatible with RIE.

Ion beam etching has many applications, including nano-machining of magnetic transducers, MEMS devices, and trimming of surface acoustic wave (SAW) and bulk acoustic wave (BAW) filters. A newer application is fabricating high-performance non-volatile memory, specifically "spin transfer torque" MRAM (magnetoresistive random-access memory).

Ion Beam Sputtering

- Atoms of target material can be ejected by bombardment of energetic ions
- An atom can be ejected, when the kinetic energy of the recoil atom exceeds the surface binding energy
- Momentum exchange between incident ions and atoms of the target material due to collision cascades
- Deposition on the substrate surface and build a thin film of the target material
- Almost any material can be deposited, stoichiometric deposition of compounds
- Low process pressure (10^{-4} mbar) and temperature (<100°C)

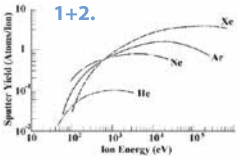


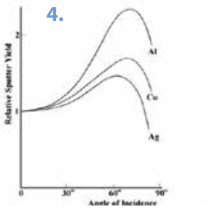
Sputter Yield

Sputter Yield is the number of removed target atoms for each incoming primary ion.

$$Y = \frac{n\ (\text{sputtered atoms})}{n\ (\text{primary ions})}$$

1. Energy of incoming ion
2. Mass ratio between incoming ion and sputtered atoms
3. Material to be sputtered (binding energy)
4. Angle of incidence of ion flux


1+2.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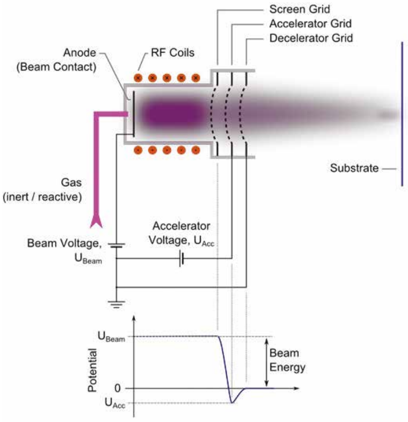
RF source as example

- Inductively coupled RF Plasma
- Grid system
- → Extraction and optics of ion beam
- MW power 0–800 W (operation range 250W–350W)
- Beam Voltage 0.05V–2 kV
- Accelerator Voltage 0.1 V –1 kV

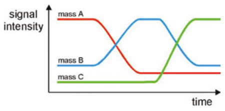


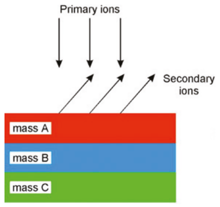
Properties of a microwave ion beam source

- High density plasma
- Long-time stability due to inner coupling instead of ICP source
- Less maintenance of the plasma cup required
- Wavelength in the range of the hardware size: standing wave effects
- Temperature and recombination effects are critical
- Tuning affects not only reflected power but also plasma density distribution in the source

End point detection by Secondary Ion Mass Spectroscopy

- End point analysis during ion etching by secondary ion signal detection
- Hardware integration and threshold level software integration
- Additional Residual Gas Analysis (RGA) and leak detection functionalities

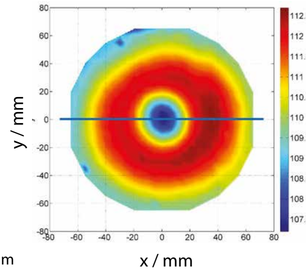




Homogeneity of etching

SiO_2 Ion Beam Milling in Argon Process

- Energy 600 eV / Current 245 mA / Rotation 20 rpm / Perpendicular incidence
- Process time 300 s at 22 nm/min
- Helium cooling applied



mean = 110.8 nm / min = 107.2 nm / max = = 112.2 nm (min–max)/(2*mean) = 2.5% / sigma = 1.1 nm

Sigma = 1.0 % for 150 mm wafer

SPECIFICATIONS

circular microwave broad ion beam source at frequency 2.54 GHz
ion energy 50–2,000 keV
sample size up to 6" wafer
He backside cooling
Loadlock
endpoint detection system SIMS HAL IMP 301/3F with accuracy 1 nm
Ar+ sputtering
reactive ion beam etching CHF3, O2, SF6

MORE INFO

Guarantor: **Marek Eliáš** (Marek.Elias@ceitec.vutbr.cz)
Web: http://nano.ceitec.cz/ion-beam-etching-scia-systems-coat-200/

CEITEC
BRNO UNIVERSITY OF TECHNOLOGY
UNIVERSITAS MASARYKIANA BRUNENSIS