VACUUM ARC ION SOURCES — ACTIVITIES & DEVELOPMENTS AT LBL

Ian Brown
Plasma Applications Group
IBT/AFRD/LBL

Lawrence Berkeley Laboratory
University of California
Berkeley

The Team ('95)

Ian Brown
Andre Anders
Simone Anders
Mike Dickinson
Bob MacGill
Othon Monteiro
Sebastien Raoux
Zhi Wang
Efim Oks (guest scientist from Tomsk)
Gera Yushkov (guest scientist from Tomsk)

Vacuum Arc Ion Source (& plasma) Developments

- Spark source / high charge state work
  - A vacuum spark, not arc. For very high charge states.
- High charge states in magnetic field
- Hybrid metal / gas operation
- Multipole work, for plasma profile flattening
- Workhorse Mevva V for many implantation applications
- Broad beam work
  - 50 cm embodiment made and used for implantation
- Macroparticle removal
  - Plasma duct installed and demonstrated

Vacuum arc ion source & beam characteristics

Extraction voltage		~ 10 – 100 kV
Ion beam energy		~ 10 – 300 keV
Beam current		~ 10 mA – 20 A
"	diameter	~ 0.1 – 50 cm
"	divergence	≥ 3^0
"	emittance	≥ 0.05 π cm.mrad.
"	length	~ 10 µs – dc
Ion	charge state	~ 1 – 6

Ion species Li, C, Mg, Al, Si, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ge, Sr, Y, Zr, Nb, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Ce, Pr, Nd, Sm, Gd, Dy, Ho, Er, Tm, Yb, Hf, Ta, W, Ir, Pt, Au, Pb, Bi, Th, U

Ion implantation

- Broad-beam mode (as opposed to scanned spot)
- Typical implantation parameters
  - Energy ~ 50 – 150 keV
  - Dose ~ 10^{12} – 10^{18} cm^{-2}
  - Range ~ 1000 Å
  - Straggling ~ 500 Å

Ion implantation research applications

Some examples of research done

- High temperature oxidation inhibition
- Corrosion resistance
- Hardening of ceramics
- Buried conducting layers in Si ($IrSi_3$)
- Buried strained layers in Si ($Si_{1-x}Ge_x$)
- Hi-T_c film compositional "tuning": Y, Cu into YBaCuO
- Fundamental study of implantation ranges in C
- Effect of implantation on diamond nucleation
- Rare earths into III-V's for luminescence, etc
- ....

Very broad beam, high current, DC embodiment

- DC plasma tests
  - 5 Amps of Ti plasma
- DC extracted ion beam
  - 600 mA of Ti ions @ 18 keV (power supply limited)
  - 18 cm diameter extractor
- Very large extractor
  - 7 Amperes of Ti ions @ 100 keV (20A peak)
  - 50 cm diameter extractor

☞ ☞ "Bigger" beams (current and size) by orders of magnitude

Macroparticle contamination

- Small metal globules formed along with plasma
  - ~ 0.1 to 10 μ in size
  - initially molten and rapidly solidified in flight
  - less, in general, for cathode materials of higher melting point
  - natural separation; flux is peaked close to parallel to thesurface
  - In general, not a problem
- But nevertheless it is in principle desirable to remove the macroparticles completely from the ion beam
- A plasma duct consisting of a bent solenoid field can do this

☞ ☞ Macroparticle-free beams have been produced

Charge state enhancement

- Vacuum arc ions are in general multiply stripped
  - Q = 1+ to 6+
  - Q = 1+ to 3+
- Ion energy can be increased by increasing the charge state rather than by increasing the implanter operating voltage
- Some recent work has shown that the application of a strong magnetic field to the arc region can provide such upward charge state control
- New high charge states created; Q increased by a factor up to 2X
  - mean ion energy can be about doubled without change in voltage

☞ ☞ Upward control of ton charge states can be effected
The effect is significant for implantation application

Hybrid metal / gaseous beams

- Vacuum arc is basically a metal ion device
- By adding gas to the discharge, gaseous species can be formed
- Allows for mixed metal / gas ion beams
- Can form buried compound layers such as oxides and nitrides
- Versatility of the source is enhanced by this capability
- Serendipitous triggering advantage
  - Arc initiated by gaseous breakdown; no high voltage pulse needed
  - No erosion of the triggering system
  - The ion source can be operated for millions of repetitive pulses before the cathode needs to be changed.

☞ ☞ Gaseous / metallic ion beams can be produced