Accelerated Neutral Atom Beam (ANAB)

Development and Commercialization

July 2015
Technological Progression

Sometimes it is necessary to develop a completely new tool or enabling technology to meet future generation processing demands.
A Brief History of Exogenisis Corporation and ANAB Development

- 1984: *Epion Corporation founded by Allen Kirkpatrick.*
- 1989: *GCIB Collaboration with Dr. Isao Yamada (Kyoto Univ., Japan).*
- 1996: *Epion delivers 1st GCIB tool to Kyoto University.*
- 2000: *Epion acquired by JDS Uniphase Corp. (JDSU).*
- 2006: *Epion acquired by Tokyo Electron Corp. (TEL), becomes TEL Epion.*
- 2006: *Exogenisis acquires GCIB rights for biomedical app’s from JDSU.*
- 2014: *Fundamental Patents issued to Exogenisis for ANAB.*
- 2015: *Exogenisis and SEMATECH form ANAB strategic alliance.*
What Are Accelerated Particle Beams Used For?

- Doping (sub-surface junctions)
- Sputtering (material removal)
- Smoothing
- Coatings
- Patterning
- Chemical Modification
- Physical Modification (amorphous region)
Ion Implantation

$^{16}O^+$

10 – 200 keV

Plasma Bombardment

$^{16}O^+$

0.1 – 2 keV

GCIB

$^{16}O^+$

10 – 30 keV

ANAB

$^{16}O^+$

10 – 100 eV

Energetic Particle Bombardment Processes
ANAB is a ‘Nano-scale’ Technique

- Ion Implantation:
  - Penetration path
  - Thermal spike
  - Damage zone

- Plasma Bombardment:
  - Penetration path
  - Thermal spike
  - Damage zone

- GCIB:
  - Amorphized hemisphere formed by thermal transient

- ANAB:
  - Amorphized layer

- Shallower process depths

50 – 1000 nm
What Are the Differences Between a Neutralized Ion Beam and an Accelerated Neutral Atom Beam (ANAB)?

• A Neutralized Ion Beam is composed of individually charged ions that are charge ‘neutralized’ with added electron flux for two reasons:
  – Low energy transport (beam blowup)
  – Target surface neutralization

• An Accelerated Neutral Atom Beam (ANAB) is composed of accelerated atoms that are not ionized.
  – Low energy / high flux (no beam blowup)
  – No target neutralization required
Charged Particle Beams Are Subject to Beam Blowup Particularly at Low Energies

*Positive charges repel each other

Flux neutralization is necessary to mitigate beam blow up
ANAB Is Not Subject To Beam Blowup At Low Energies

Flux neutralization is not necessary
Ionized Particle Beams Require Complete Surface Neutralization to Avoid Damaging Discharges Through Insulating Materials

Charged Particle Processing $\rightarrow$ Charge Accumulation $\rightarrow$ Capacitive Discharge “Damage”

Ion beam processing with improper surface neutralization
ANAB Does Not Require Target Surface Neutralization

ANAB Processing → No Charge Accumulation → NO “Damage”

“ANAB simplifies processing”
Accelerated Neutral Atom Beam Generation

1. Expansion of gas through a supersonic nozzle creates gas clusters

Ar

a few hundred to several thousand Ar atoms bound by weak interatomic forces
Accelerated Neutral Atom Beam Generation

2. Clusters are ionized by electron impact and accelerated through HV

Individual atoms of an ionized 1000 atom cluster have 30 eV/atom after 30 kV acceleration
Accelerated Neutral Atom Beam Generation

3. Collision of an accelerated cluster ion with an un-accelerated gas atom makes the cluster thermodynamically unstable.
Accelerated Neutral Atom Beam Generation

4. Absorbed collision energy overcomes weak interatomic forces

atoms released from a cluster continue to travel with the same speed and direction they had as part of the cluster
Accelerated Neutral Atom Beam Generation

5. An electrostatic field is used to deflect residual charged species from the beam.
Accelerated Neutral Atom Beam Generation

6. Accelerated neutral atoms continue to transport as an intense collimated beam

accelerated neutral atoms have energies controllable from 10 to 100 eV
Accelerated Neutral Atom Beam (ANAB)

- High Intensity Flux
- Low Energy Particles (10-100+ eV)
- Electrically Neutral (never ionized)
- Surface Penetration $\leq$ 3 nm

3. Additional applications pending.
What Are The Unique Properties of ANAB Processing?

- Controlled nano-depth surface modification while maintaining bulk material properties.
- All material modifications are limited to the amorphous region.
- Low thermal budget.
- High process flux / No surface neutralization required.
ANAB Nanoscale Surface Modifications

Accelerated Neutral Atom Beam
ANAB

silicon surface

amorphous layer 2.1 nm

10 nm
ANAB Controlled Surface Modifications

- Smooth: most materials to angstrom level smoothness.
- Sputter: controlled material removal / selective removal.
- Surface activation: hydrophilic response.
- Chemical modification.
- Implant dopants.
- Deposit films.
- Pattern / texture surfaces.
ANAB Enhanced Performance Applications

• Surface Structure Modification/Amorphization
  – ultra-thin membranes
  – non-additive organic diffusion barriers
• Surface Texture Modification/Smoothing/Patterning
  – UV/EUV Optics
  – Bio-integration/enhanced cell attachment
• Surface Energy Modification/Hydrophilicity
  – Bio-activation of non-bioactive materials
  – Nano-fluidics
• Surface Chemistry Modification
  – Ultra-shallow doping
  – Composite interfaces/coatings
Hydrophilic Response

ANAB Increases surface hydrophilicity

Teflon

Ti
Enhanced Bioactivity

Influence upon living cell behaviors
PEEK (polyetheretherketone) surfaces after 14 day exposure to osteoblast cells

Untreated Control

Treated by Accelerated Neutral Atom Beam
ANAB Processing of Inert Materials for Enhanced Healing and Osseointegration

Inter-body Device for Spinal Fusion

Cells now Attach and Proliferate
Elution Barrier Formation

Creation of a non-additive ‘Diffusion Barrier’ for controlled drug release rates via ANAB processing
ANAB Enhanced Drug Elution

- Polymer free drug delivery.
- An elution barrier that can be tailored to deliver drug/protein over prescribed time.
ANAB Enhanced Adhesion

ANAB Enhances Adhesion of Coatings
Epoxy Adheres to ANAB Treated PEEK in ASTM Tension Testing
Study Conducted for Orthopedic Implant Customer

PEEK
Green epoxy
Stainless Steel

ASTM F1147 Setup for static Tension testing

Control
NanoAccel Processed Cylinder

No epoxy adheres to control PEEK cylinder
Epoxy adheres nearly entirely on PEEK cylinder processed with ANAB
ANAB Smoothing
EUV Lithography Mask Blank Substrate

Exogenisis process

Ra 1.219 nm
Rz 11.221 nm

After Accelerated Neutral Atom Beam

Ra 0.133 nm
Rz 1.406 nm
ANAB Enhanced Membranes

Pellicle material processing for enhanced transparency
Ultra-Shallow Surface Doping

Incorporate Various Gasses

- $\text{O}_2$, $\text{N}_2$, $\text{CH}_4$
- $\text{NF}_3$
- $\text{B}_2\text{H}_6$, $\text{PH}_3$, $\text{AsH}_3$
- $\text{GeH}_4$, $\text{SiH}_4$

{1-3nm}
ANAB Enhanced Oxidation Resistance

Oxidation accelerated at ~200deg C in air
Exogenesisis Has Formed The Following Development/Commercialization Alliances

- **Biomedical**
  - Next generation drug eluting stent based on ANAB technology.
  - Enhanced integration spinal cages and enhanced wound healing products.

- **MEMs**
  - Advanced DNA imaging (TEM) grids.
  - Functionalized surfaces for enhanced imaging.

- **Semiconductor**
  - SEMATECH Strategic Alliance.
  - Pellicle Materials (Ultra-thin membranes).

- **High-Energy UV & EUV Optics**
  - Increased laser damage thresholds.
  - Surface hardening.
  - Surface passivation.
Exogenesis is interested in forming relationships for commercializing ANAB technology.

Please visit us at “Innovations New York” booth for more information.
Thank You

We Appreciate Your Interest