Plasma-based Thin Film Depositions

Applications, Limitations, Our Improvements, and Case Studies

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Outline

About Ascentool

Various sputtering deposition technologies,
Our improvement and
Selected applications

Common issues and requirement

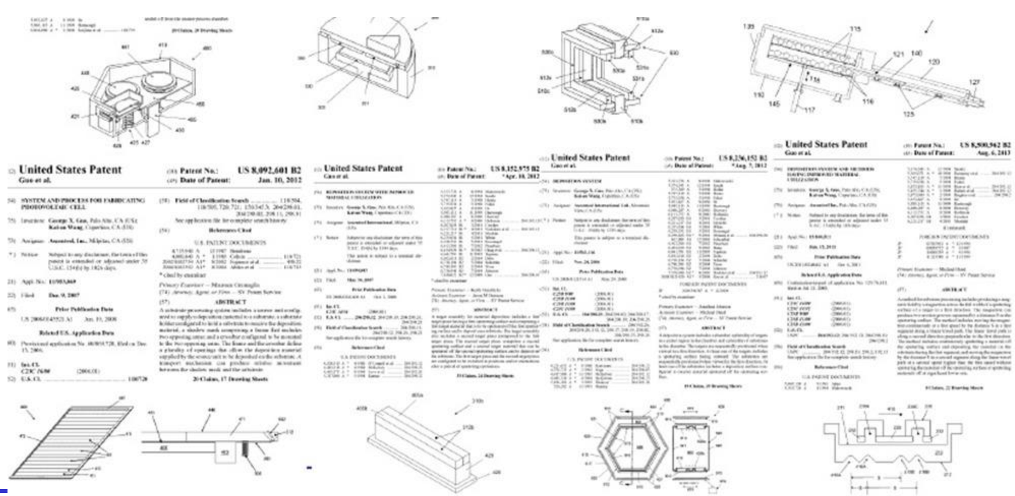
The "Best Against Nature™" solutions

Application in PECVD

Summary

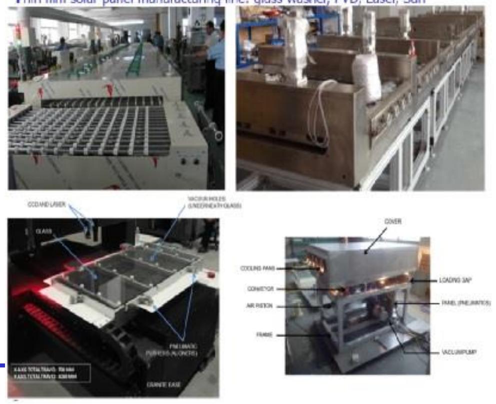
About Ascentool: George.Guo@ascentool.com, 650-704-8028

1. Founder developed numerous #1 market share PVD, PECVD, MOCVD products;
2. Ascentool was founded in 2005 to innovate at low cost:
   - Accumulate multiple skills in a small team to carry out closed loop thinking and generate break through concepts;
   - Use our device & equipment knowledge to work with customers and generate solutions;
   - To work with outside contractors, suppliers and partners to deliver these solutions.
3. We invented platforms, deposition sources, & unique processes. We help customers solving their issues and gain competitive advantages. (see right). We believe our latest platform/source solution to be the Best Against Nature™ for most thin film deposition applications.



30MW CIGS Line

Thin film solar panel manufacturing line: glass washer, PVD, Laser, Sun



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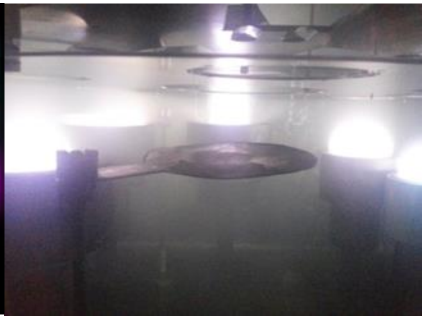
Sputtering Applications: Fixed Round Planar Magnetron



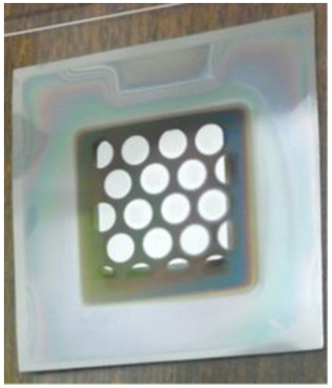
Hardware Pro/Con:

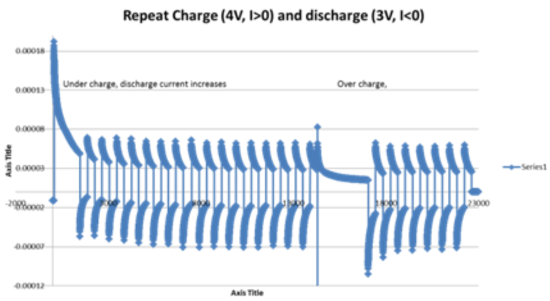
It is simple and easy to integrate into equipment.
Wide selection of target materials, low target cost

But poor material utilization, hard to make uniform film, very different conditions from production equipment, and generate particles (no full face erosion)

Thin film battery application:

LiCoO/LiPON/(C or Si) on Al and Cu conductor layers.
Metal foil or Glass substrates





Challenges to go into production:

Any pinhole or defect in electrolyte layer will cause short, and reduce charge retention and capacity

The storage capacity is proportional to cathode/anode thickness. A low cost and high volume deposition tool is required.

Sputtering Applications: Fixed Round Planar Magnetron

CdTe PV cell application:

Glass/TCO/CdS/CdTe/Cu/Au. Sputtered P/N layers

Challenges to go into production:

Any pinhole or defect in P/N layer will cause short, and reduce cell efficiency

Need to have thick absorption layer. A low cost and high volume deposition tool is required.

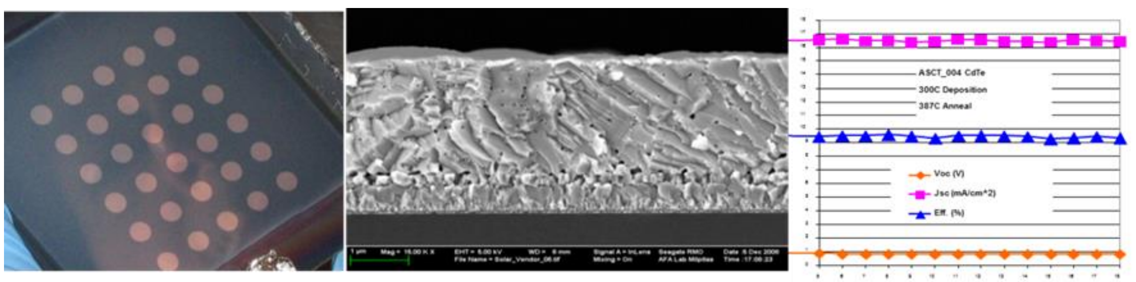


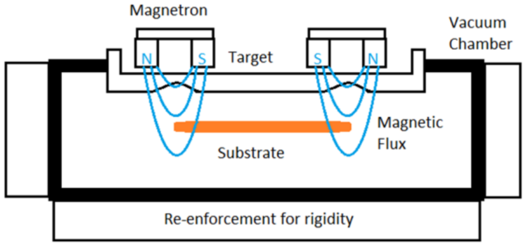
图 4. （左）亚升通于2006年用实验室PVD设备在75mm x 75mm基片上制备的碲化镉薄膜电池。（中）该电池的扫描电子显微镜截面照片，最厚的一层为碲化镉（CdTe）吸收层。（右）该电池的电性能测试数据，平均光电转换率为9.3%。

Sputtering Applications: Rotating Circular Planar Magnetron

Hardware Pro/Con:

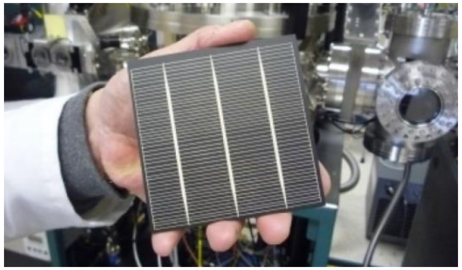
Full target erosion. Close distance from substrate to achieve higher deposition rate.

Waste lots of materials outside substrate area, even more wasted if the substrates are not circular shaped. Non-uniform plasma damages on substrates. Difficult to achieve uniformity for high volume rectangular substrates.

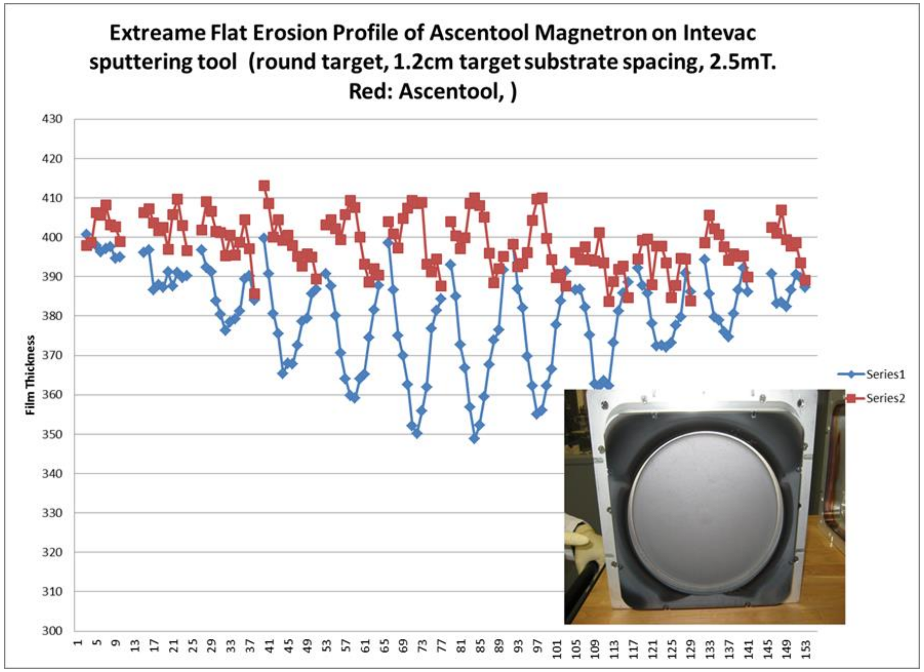


CIGS on 125mm square substrates:

Leverage Si module infrastructure, make individual CIGS solar cells on glass substrates.



To achieve high material utilization and high deposition rate. Ascentool optimized the center erosion and achieved high utilization and much better uniformity



Challenges to go into production:

Still waste lots of materials due to low collection efficiency form deposition source (about 50%)

Small area processing.

Sputtering Applications: Rectangular Planar Magnetron

Hardware Pro/Con:

Planar targets are cheaper and have better material properties than rotary targets.
Stationary magnetron is simple, easy to integrate into systems, but have low material utilization and no full face erosion.

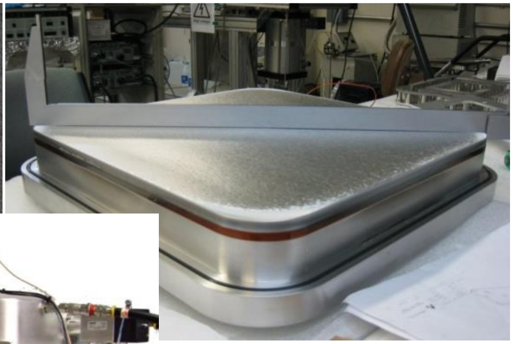
Scanning magnetron can improve material utilization but limited by the low edge erosion in narrow target, and deep erosion in the end in wide target. It has full target erosion, but harder to incorporate in in-line system.

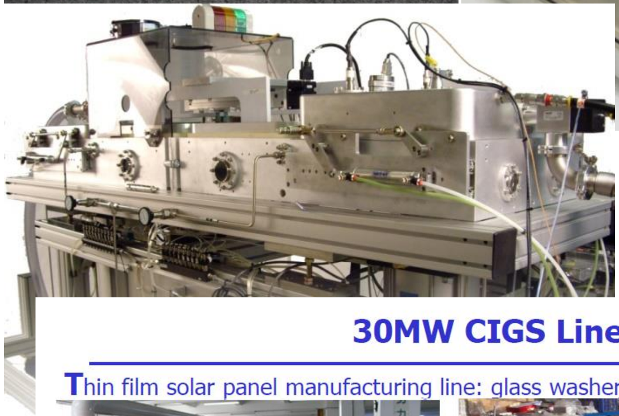
Application: CIGS on large glass:

Flat erosion ensure CIGS composition uniformity.
Large target for stationary deposition.

Challenges to in production:

Limited target utilization. Requires target bonding. Only process one row of substrate at a time. Plasma heating cause composition change due to evaporation of low melting temperature elements.





Step & Sputtering: Rectangular Planar Magnetron

Hardware Pro/Con:

Combine the advantages of scanning and fixed magnetron.

Application: CIGS on large glass:

Scan and Stop source for continuous in line deposition: optimized target utilization and simple integration of the source and system

(63) Continuation-in-part of application No. 12/176,411, filed on Jul. 21, 2008.

(51) **Int. Cl.**

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C23C 14/32	(2006.01)
C25B 9/00	(2006.01)
C25B 11/00	(2006.01)
C25B 13/00	(2006.01)

(52) **U.S. Cl.**
USPC **204/192.12**; 204/192.13; 204/298.19; 204/298.2

(58) **Field of Classification Search**
USPC 204/192.12, 298.19, 298.2, 192.13
See application file for complete search history.

(56) **References Cited**

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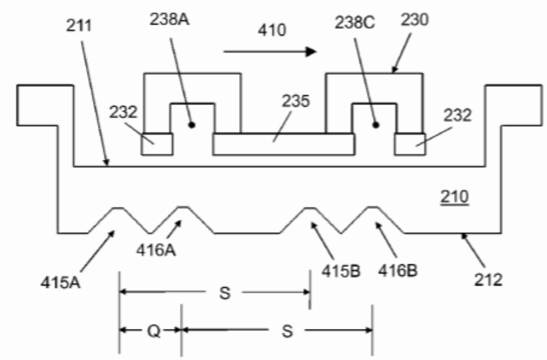
(57) **ABSTRACT**

A method for substrate processing includes producing a magnetic field by a magnetron across the full width of a sputtering surface of a target in a first direction. The magnetron can produce two erosion grooves separated by a distance S on the sputtering surface. The method includes moving the magnetron continuously at a first speed by the distance S in a first segment along a linear travel path. The linear travel path is along a second direction perpendicular to the first direction. The method includes continuously sputtering a material off the sputtering surface and depositing the material on the substrate during the first segment, and moving the magnetron by the distance S in a second segment along the linear travel path at a second speed higher than the first speed without sputtering the material off the sputtering surface or sputtering materials off at significant lower rate.

8 Claims, 22 Drawing Sheets

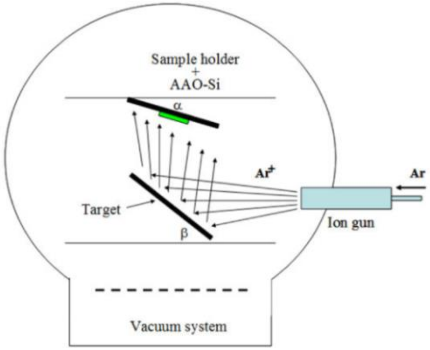


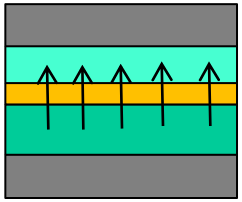
Sputtering Applications: Ion Beam Sputtering

Hardware Pro/Con:

Easy to prepare target material: small size or irregular shape OK. Great for R&D

But the rate is low



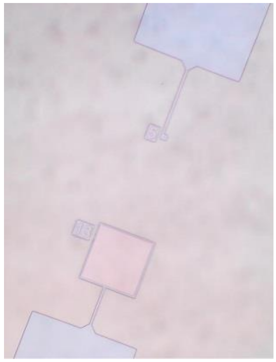


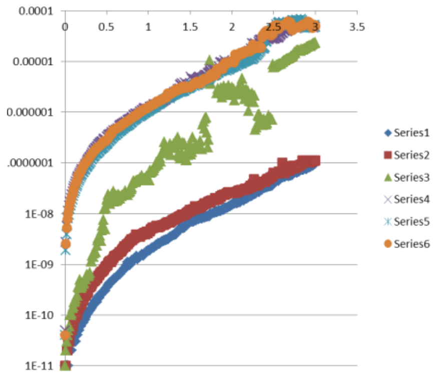
Oxygen ions move under voltage & change stack resistance

Non-Volatile Memory (Memoria LLC, depo @ M.Oye/NASA)

Si/Pt/MO1/MO2/MO3/Pt

Resistance changes due to movement of oxygen

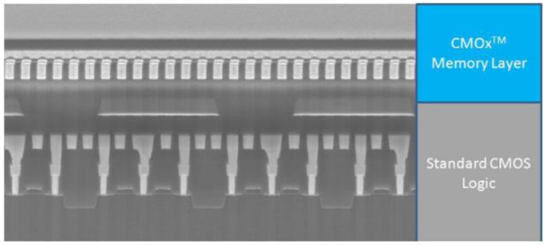




Challenges to go into production:

Increase deposition rate, high quality oxide: no pinhole and high break down voltage

Trade off between data retention time and read/write speed.



Sputtering Applications: Rotary Magnetron

Hardware Pro/Con:

High target utilization, easy to integrate into in-line systems, increasing market share. Longer time between maintenance.

But target cost is higher, the target density or/and impurity level are worse than planar target.
More complex system and require more frequent servicing.
Many sources are needed for stationary deposition.
Still have plasma damages under erosion grove.

Ascentool does not have this product and no application. We are going to work with source providers for integrated systems:

Ascentool would not be able to invent this source since it is against our engineering principles: dynamic vacuum and water seal, direct water to vacuum interface, and more expensive way to make lower quality target material.

Sputtering Applications: Inverted Cylindrical Magnetron

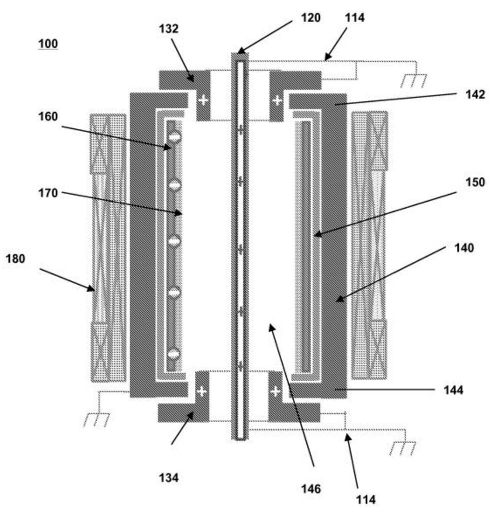
Hardware Pro/Con:

Deposition from 360 degrees, suitable for 3-D object.
Stable plasma, good composition uniformity,

Expensive for thick targets, complex mechanism to achieve uniformity for multiple substrates. Not suitable for large rectangular substrates

Applications:

Medical devices



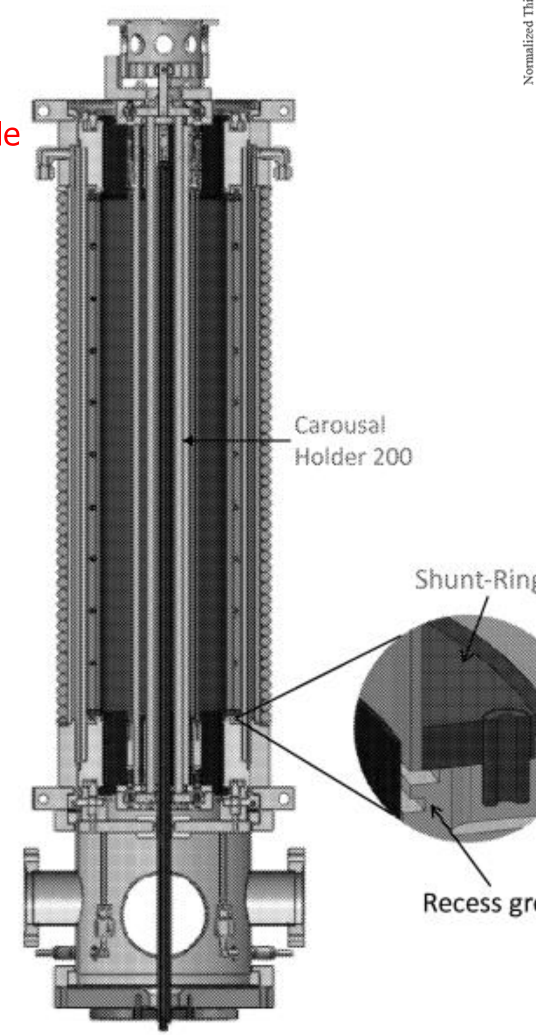


Fig. 6b

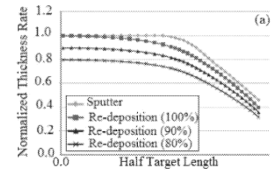


Fig. 2a

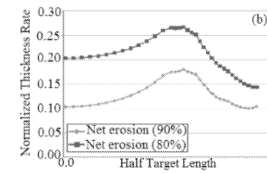


Fig. 2b

Common Requirement for manufacturing equipment:

Low cost of ownership:

Many applications requires thick film, and/or large area. The cost per kg of materials deposited determines economical feasibility for the applications

Low defect density and consistency within & between substrates:

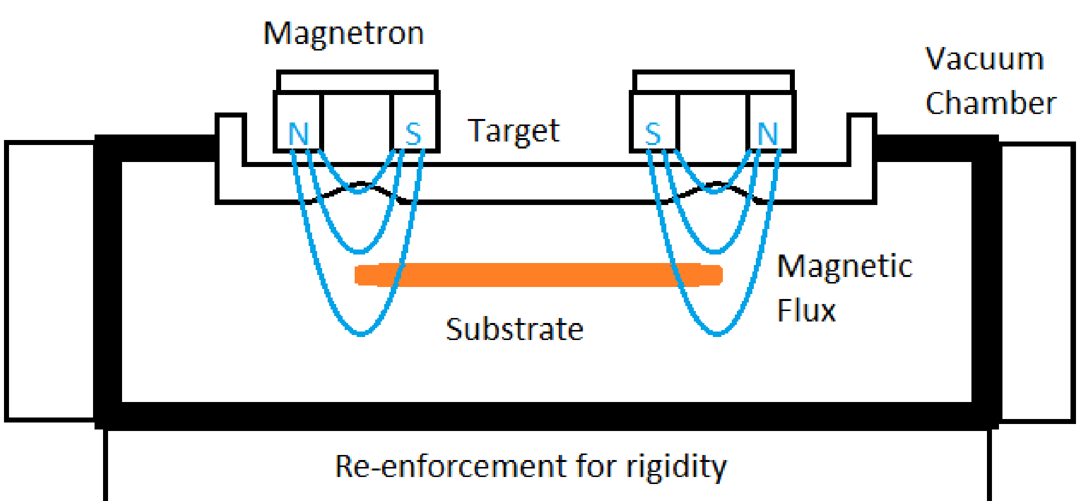
It determines the technical feasibility for many applications. The defect include intrinsic film properties such as pin-holes, low breakdown voltage, plasma damages, in addition to particulates.

Manufacturing equipment at forefront of technologies:

Large capital spending increase the barrier of entry for an application. Technology improvement can obsolete manufacturing systems, and give newcomer advantages. This make our customers reluctant to invest in large manufacturing capability. It is desirable the have a manufacturing system that reach the limit of nature and have wide range of capabilities.

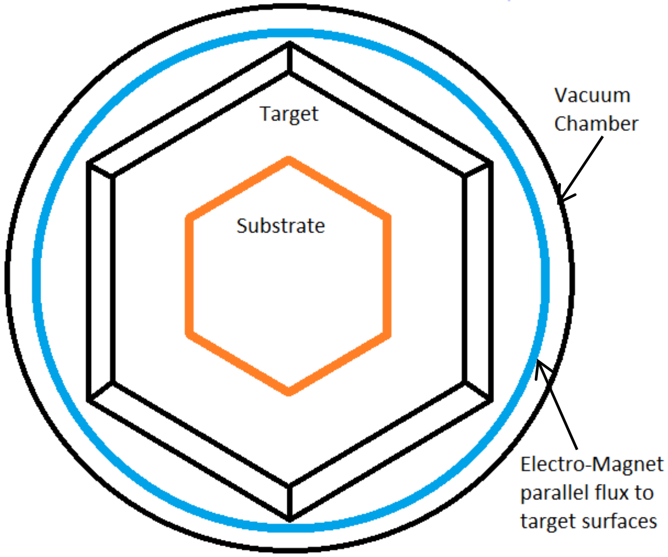
The issues with conventional production PVD

Features	Issues
• Small plasma area • Erosion form close loop on one target	• Limited depo rate, hi target voltage, ion damage • Low target utilization, intrinsically non-uniform
• Magnetic flux from target to substrate • Small target to substrate distance	• Electrons follow flux and damage substrate • More ion and electron damage, heating, arcing
• Material wasted outside substrate • 1 substrate per box shaped chamber • Thick chamber walls and enforcement • Many chamber weld (>12+2*enforcement)	• Low total material usage: around 20% equivalent • Higher cost, low throughput • Heavy, high cost, and still deforms • High labor cost and high machining cost



Improving every aspects of PVD system

Features	Benefits
• up to 100X plasma area • Erosion forms close loop on many targets.	• Hi depo rate, low target voltage, less ion damage • Near 100% target utilization and near 100% material collection, and intrinsically uniform
• Magnetic flux parallel to targets • Larger target to substrate distance	• Electrons follow flux and does not reach substrate • Less ion damage, heating, and arcing
• Targets enclose substrates • 3 times more substrate per chamber • Thin chamber wall & no enforcement • Fewer chamber weld (3 large weld)	• Material usage near 100%. Less edge effect • Reduce chamber, pumping, power, gas line cost • Light, low cost, and less deformation • Much lower labor cost and lower machining cost



Ascentool Deposition Source

Based on our issued patent where plasma forms a 3-dimensional closed loop surrounding two substrates placed back to back (not shown). Below is the cross sectional view

See application file for complete search history.

(54) MAGNETRON SOURCE FOR DEPOSITION ON LARGE SUBSTRATES

(76) Inventor: George Xinsheng Guo, Palo Alto, CA (US)

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(21) Appl. No.: 11/363,024

(22) Filed: Feb. 27, 2006

Publication Classification

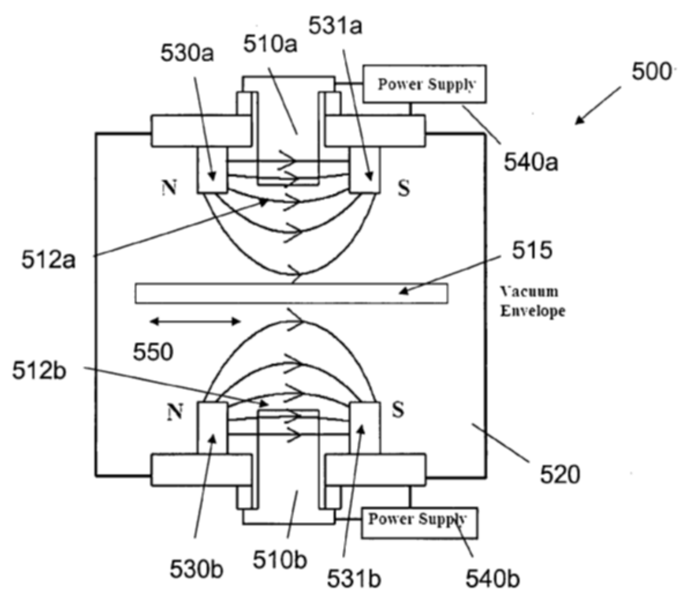
(51) Int. Cl.
C23C 14/00 (2006.01)

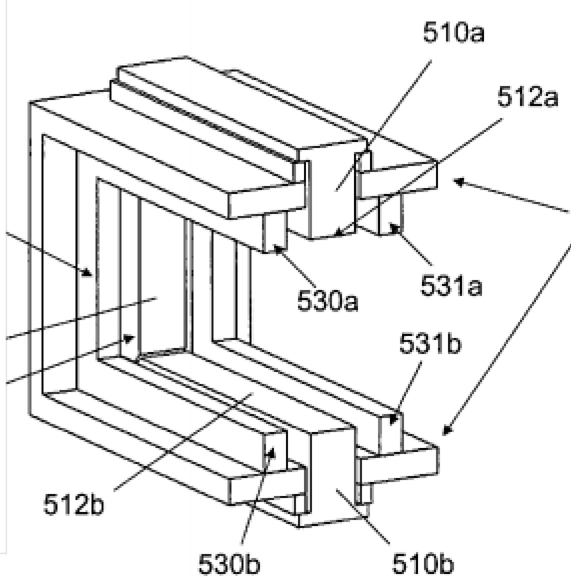
(52) U.S. Cl. 204/298.16

(57) ABSTRACT

A magnetron source for producing a magnetic field near a surface of a target in a deposition system include a first magnet, a second magnet separated by a gap from the first magnet along a first direction, and a target holder configured to hold the target in the gap between the first magnet and the second magnet. The target includes a sputtering surface from which target material can be sputtered and deposited on a substrate. The target holder is so configured that the sputtering surface is substantially parallel to the first direction and the first magnet and the second magnet can produce a magnetic field near a surface of the target.

23 Claims, 13 D

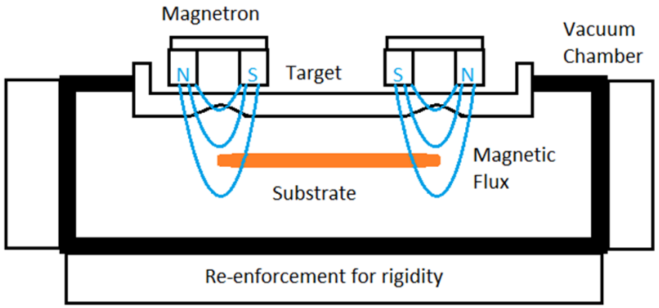




Our Best Against Nature™ (BAN) vacuum deposition is 2.5 to 10x better

Increase material utilization and reduce material cost:2.5X

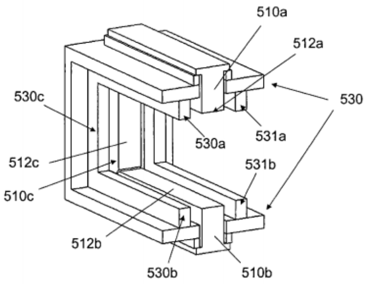
Planar target cost less but has poor utilization
Rotary target has high utilization, but also high cost/quality issues
Waste large amount of materials outside substrate
BAN: High utilization planar target: >2.5X cost improvement



Increase system throughput and lower system cost: 4X

One row of substrates processed at a time only;
Require rigid vacuum chamber for mounting deposition sources,
Needs heavy chamber and many welds

BAN: Process both sides at same time, multiple rows can be processed at same time, internally mounted source does not require large flat mounting surfaces: allow for deflection->thinner walls and fewer welds
4X improvement in throughput per system

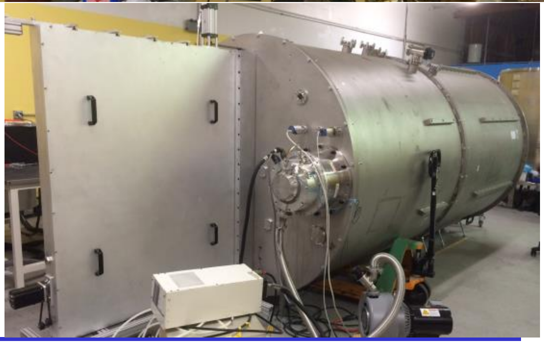


Intrinsic uniformity, low plasma damages: 10X

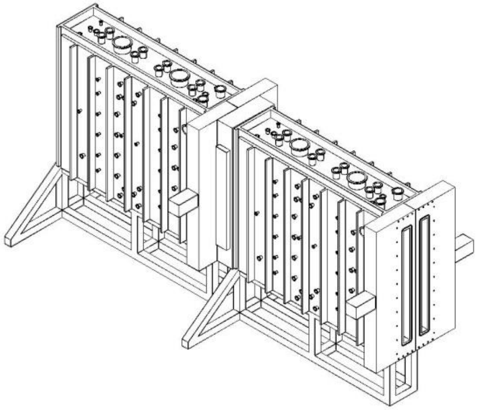
Conventional deposition sources is intrinsically non-uniform in term of plasma density and deposition angles; higher DC, peak to peak voltage damage substrates. Plasma leakage cause heating and damage.
BAN: 360 degrees deposition from uniform plasma, confine all energetic electrons, lower voltage by 10x, increase plasma area to reduce damages.
Decrease plasma heating of substrate/increase deposition rate.

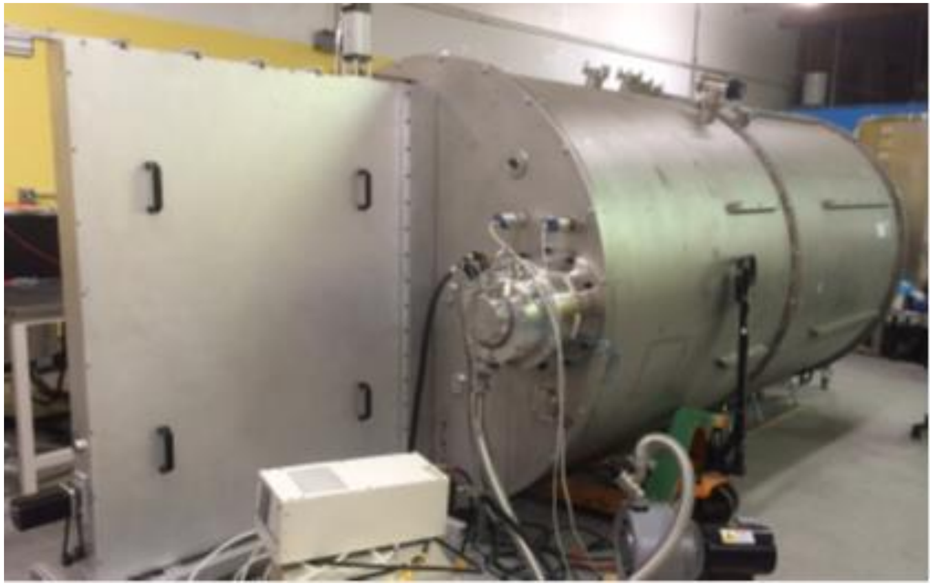
Increase PM interval: 10X

Conventional deposition deposit similar thickness on shields to achieve good uniformity, limiting PM interval.
BAN: 95% of deposition materials goes to either substrates or opposing target, reducing deposition on shield by 20X. Combined with our 4x thicker target and 2.5x utilization, we can improve our PM time by 10x



Production system, with cylindrical or box chamber





Gas Utilization in PECVD

Wide pressure process window

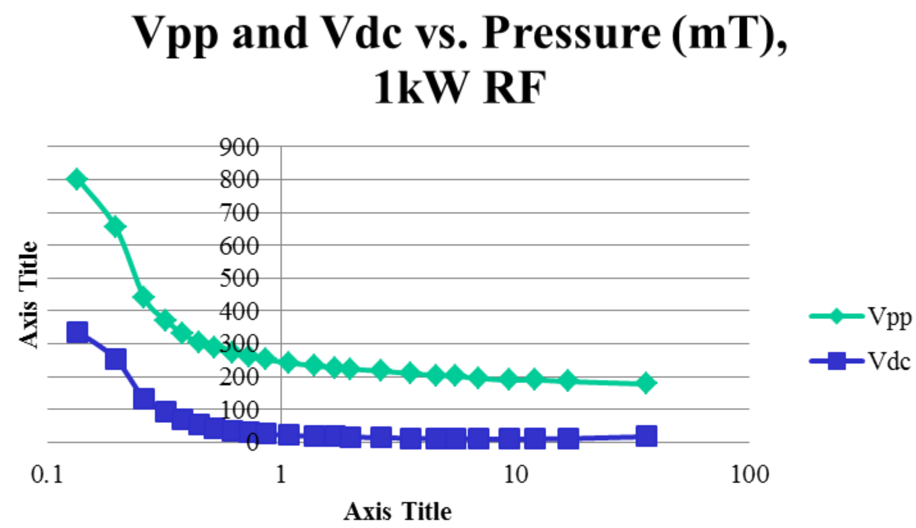
RF and DC can run from 0.1mT to 500mT

Gas distribution and shower head replace targets, all other parts same as PVD.

Gas utilization almost 100% at low pressure and high power:

Enough activation power

Low gas phase reaction



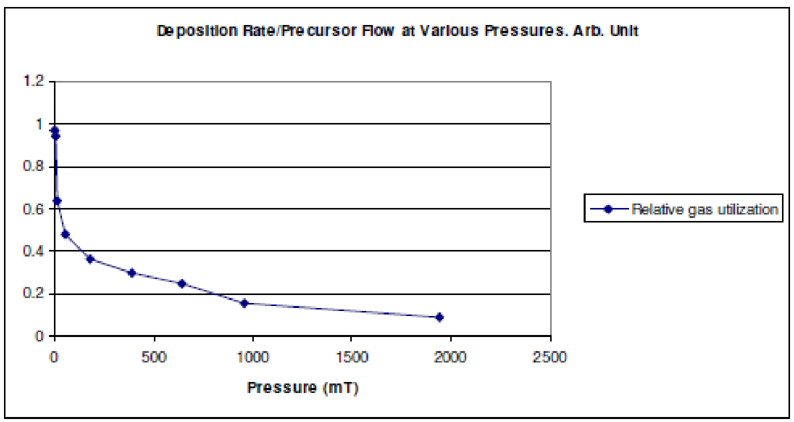
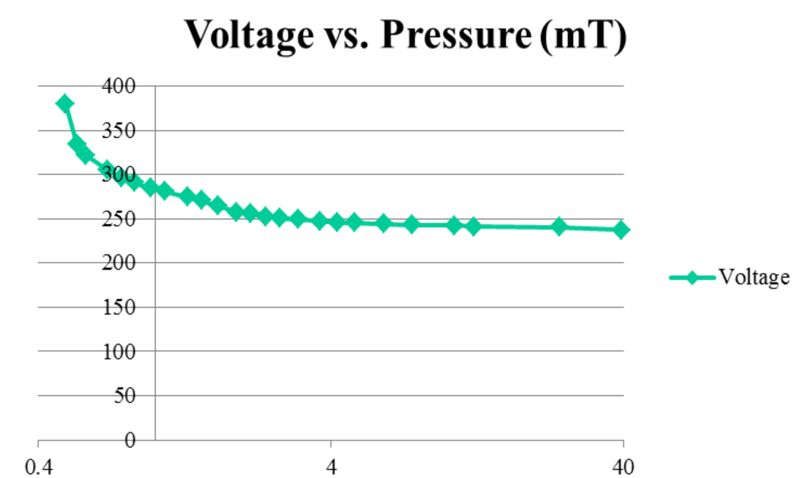


Fig.6: More deposition per unit of flow at lower pressure

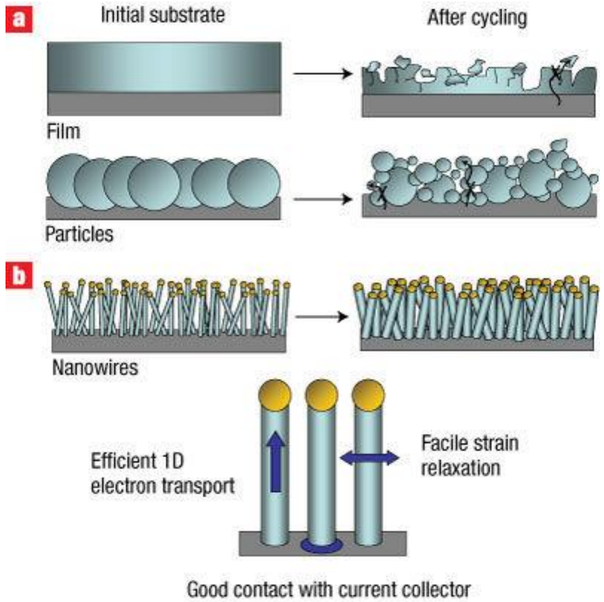


PECVD Applications: Magnetron Enhanced

Hardware Pro/Con:

High density plasma to ensure 100% breakup of precursor gases
Low pressure reduces gas phase reactions and high material utilization
Wide process window (0.1mT to 500mT), 30-3000Watts RF
Low peak to peak and DC voltage. Can run DC for conductive films.

But more deposition on shower head in DC mode

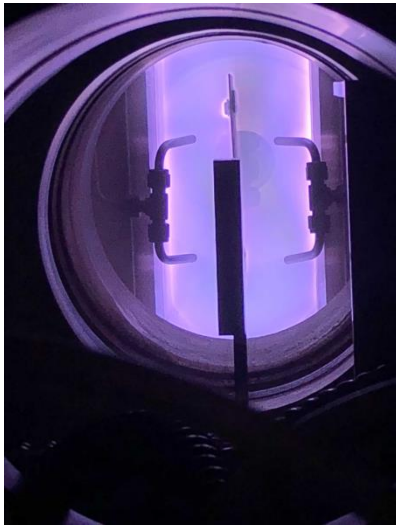


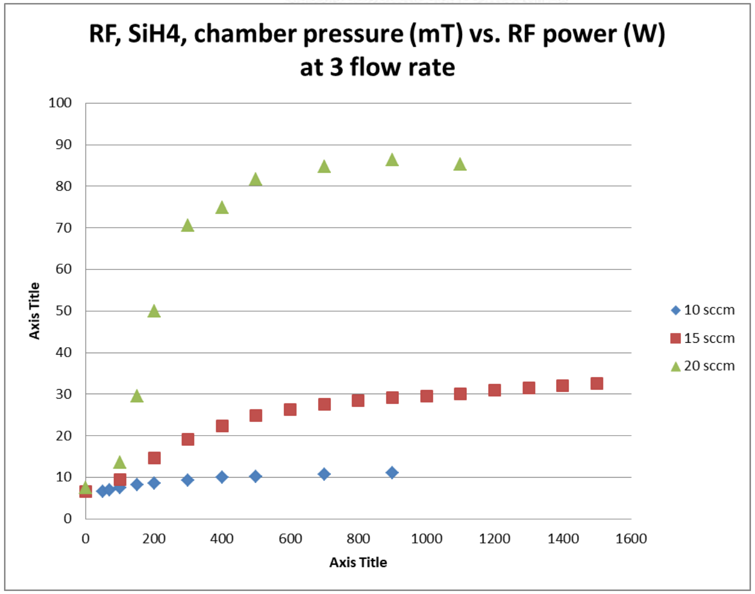
Silicon Anode application:

Si on micro-structured anodes. Requires high material utilization, high deposition rate, and adequate step coverage. Our sputtered Si does not have enough step coverage.

Challenges to go into production:

Low cost, high volume (deposited weight is huge), covert material near 100% and collect near 100% on substrates, chamber material buildup, substrate handling,…





Summary

Ascentool
developed various source/system/process technologies,
works with customers on applications and most suitable solutions
works with suppliers to deliver solutions

Various sputtering deposition technologies,
Our improvement and selected applications
Fixed circular magnetron, rotating circular magnetron, fixed planar magnetron, scanning planar magnetron, step and sputter, rotary, ion beam sputtering, inverted cylindrical magnetron

Common issues and requirement
Low defects and high quality film, low cost of ownership, manufacturing system stay at forefront

The ideal solution
Everything perfect

The "Best Against Nature™" solutions
Best we can do based on simplicity, still 2.5 to 10x better

Application in PECVD
Low pressure, high density plasma to achieve high material utilization and low plasma damages

THANK YOU!