Plasma-Therm

MEMS trench sidewall smoothing

by dry plasma HDRF technology

(High Density Radicals Flux)

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Business Development Manager

Confidential

Outline

- HDRF Technology characteristics
- TSV technical challenges & MEMS/MOEMS applications
  - Bosch polymer removal
  - Sidewall smoothing
- Summary

Plasma-Therm, LLC

40+ Year Legacy of Technology Innovation

1974 — Origin: RF power supplies

1975 — Incorporated

1983 — Industry first single wafer production plasma etch reactor

1990 — Relocated to St. Petersburg, FL

1994 — First ever Photomask plasma etch system introduction

2000 — Acquired by oerlikon

Headquarters in FL, USA

2009 — *Established* Critical machining capabilities

2010 — REV-TECH MANUFACTURING SOLUTIONS

2011 — *Launched* Industry first Plasma dicing System in production

2013 — *Acquired* HDRF™ Stripping/Cleaning

2014 — CELEBRATING 40 YEARS OF INNOVATION

2015 — ADVANCED VACUUM *Acquired*

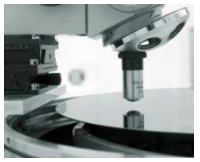
2016 — *Partnership* Combined solution

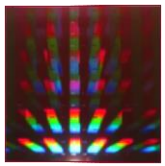
Plasma-Therm and DISCO

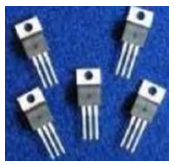
2017 — IBE / IBD *Acquired*

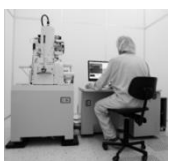
Plasma-Therm and mems.star

Etch and Deposition Solutions Across Markets







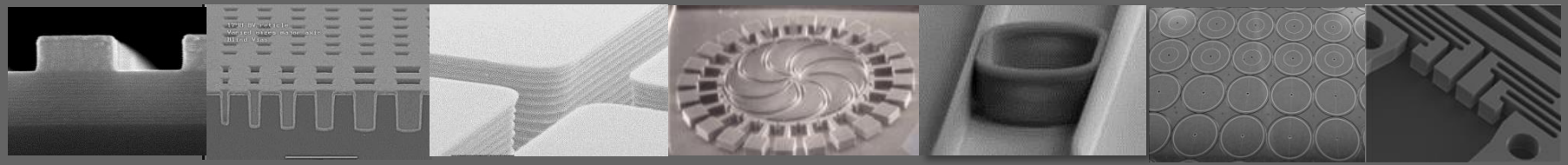


Adv. Photomask & Imprint	Wireless	Solid State Lighting	Photonics	MEMS NEMS	Power	Solar	Data Storage	Failure Analysis	R&D

Etch Solutions: ICP, RIE, PE, PHF-RIE, DRIE, HDRF, IBE, HF release

Deposition Solutions: PECVD, ICP CVD, IBD

Plasma Dicing Solutions

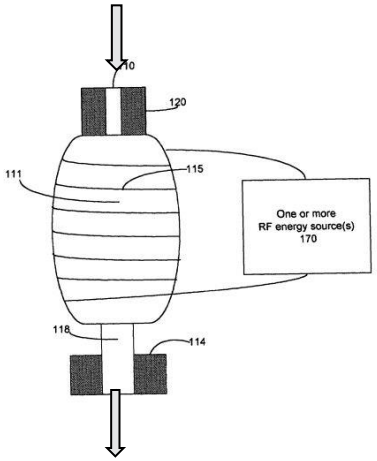


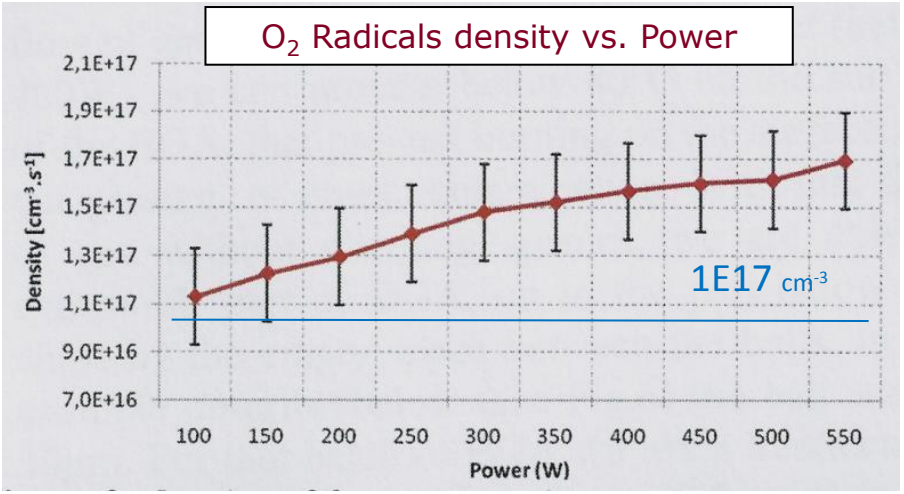
HDRF™ technology

High Density Radical Flux

- Scalable ICP source acc. wafer size
  - Distributed plasma source
  - RF 13.56MHz technology
- High plasma density
  - Radicals density > 1E17 cm^{-3}
  - Dissociation rate >90% at low power
  - Reduced ion flux at substrate level

ICP discharge tube



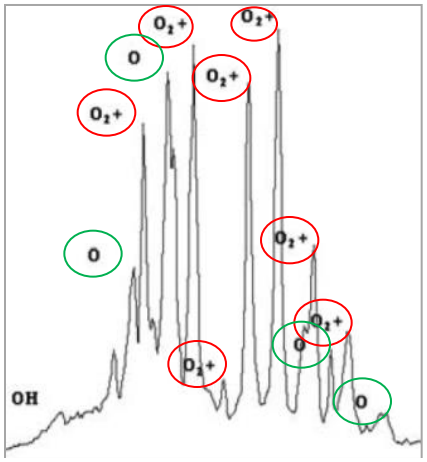


Measured by actinometry (University of Orleans, France)

HDRF™ technology

High Density Radical Flux

Conventional RF



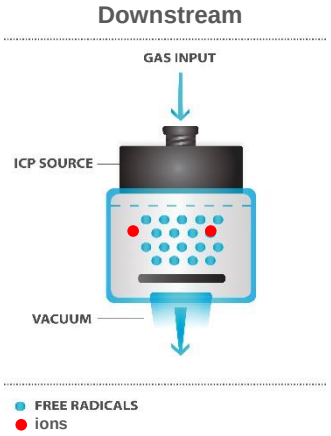
Active species: O* + Ions

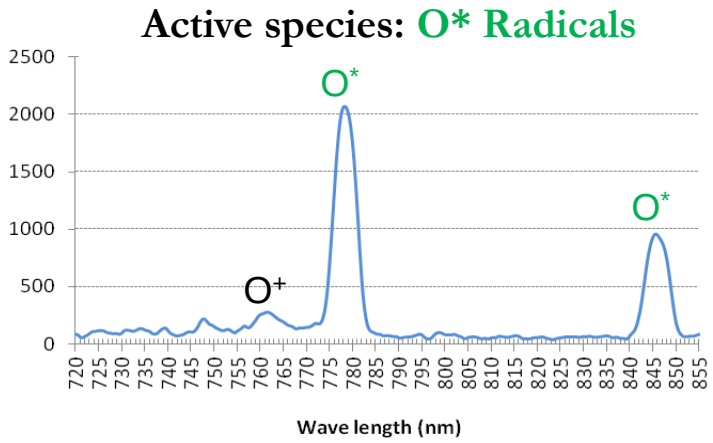
Ions concentration

Bombardment of sensitive layer = damage

Overheating of substrate

HDRF™ technology





- **High plasma density ICP source**
  - Radicals density > 1E17 cm^{-3}
  - Mainly O* radicals at wafer level
- **Low damage on sensitive devices**
  - Low ions at wafer level
  - Low temperature processing < 80°C

HDRF™ applications

Stripping, cleaning, release

Process	Attributes
Resist stripping	Low temperature (50C -150C) Double-side stripping High Strip Rate
Surface & trench cleaning	Bosch polymer removal after DRIE Smoothing DRIE scalloping Organic residues removal
Release of organic sacrificial layers	Low temperature dry release of polyimide and photoresists

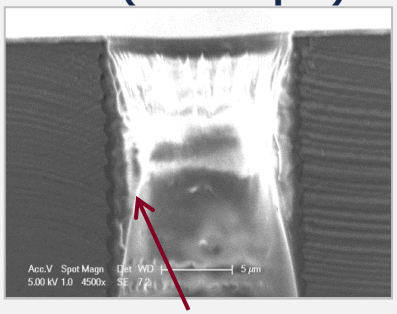
DRIE polymer removal

Before HDRF

MEMS microphone

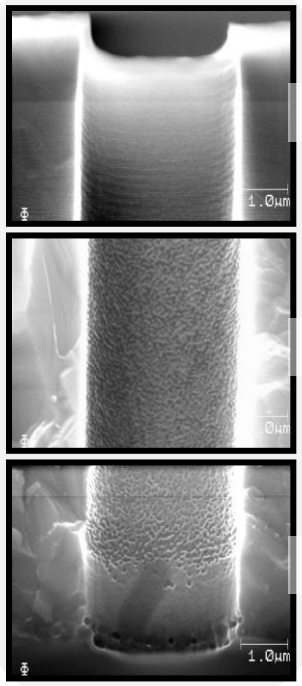
polymers

Via (10x200µm)



1.5 µm thick polymers

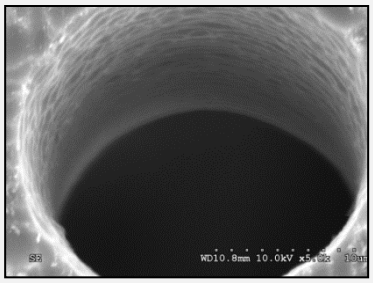
Inertial MEMS - Via (3x23µm)

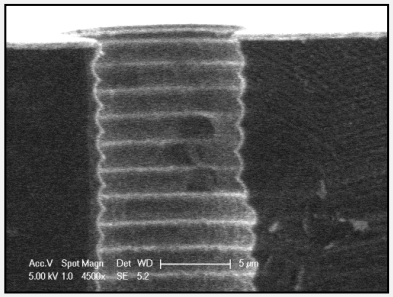


Bosch polymer removed

Confirmed by Auger analysis

After HDRF



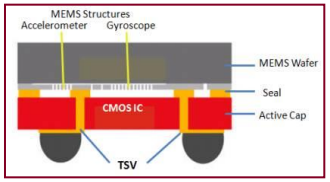


Bosch polymer removed in any size or any shape

TSV (Through Silicon Via)

DRIE scallops smoothing

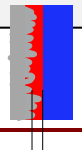
TSV connection



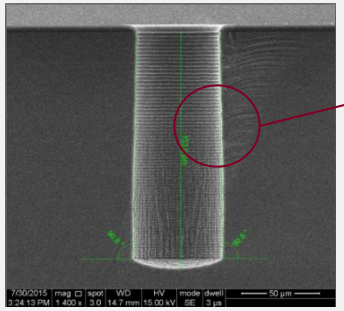
TSV process flow

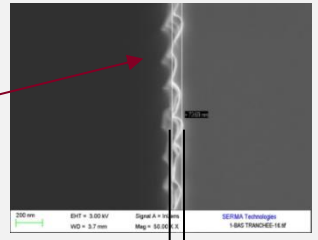
1. PMER photolithography
2. DRIE
3. PMER remove & CMP (back side)
4. Thermal oxidation & Ti/Cu deposit
5. Cu electrolytic plating
6. Ti/Cu remove (back side)
7. UBM formation (ENIG)
8. Flip chip bonding

Scallops generate non conformal oxide deposition **potential electrical leak from Cu-Si**



Bosch process

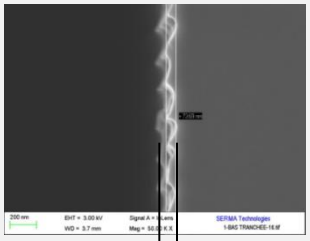




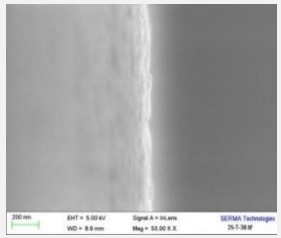
100 nm scalloping

Solution

-> scallops smoothing by plasma

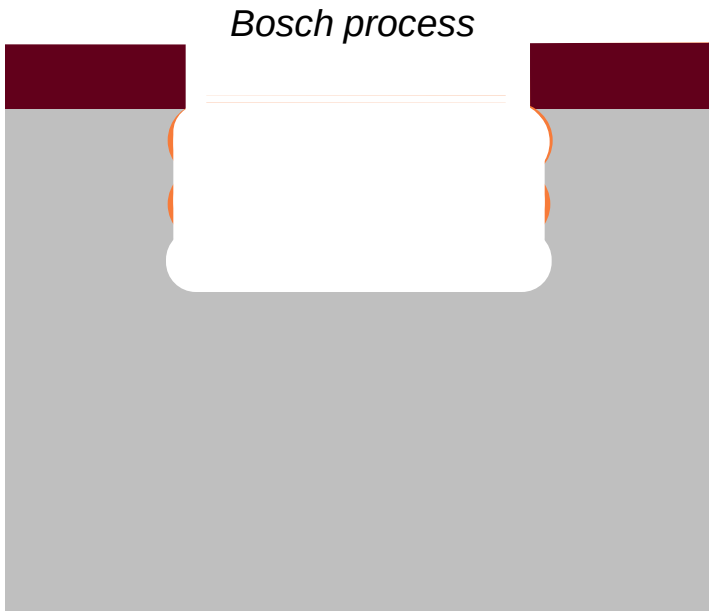


100 nm scalloping



Smooth surface after 2min process time

DRIE scallops smoothing



1/ Deep trench etch by DRIE Bosch process

2/ Bosch polymer removal by HDRF

3/ Scallops smoothing by HDRF

No CD loss after scallops smoothing

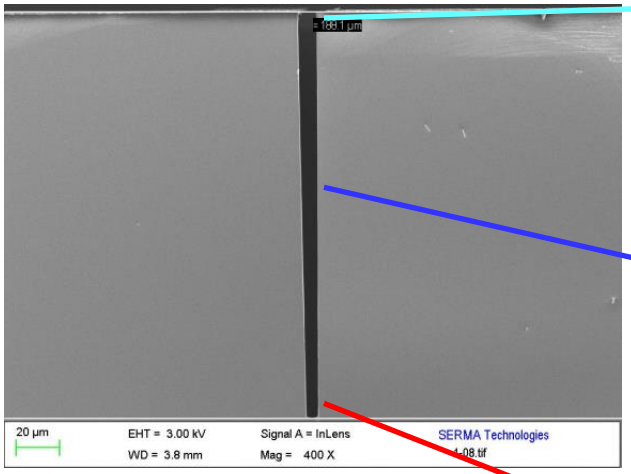
as only peaks are etched, valleys still protected

MEMS high aspect ratio

DRIE scallop smoothing

Scallop smoothing in high aspect ratio structure

Aspect ratio 30:1

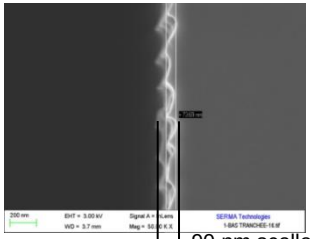


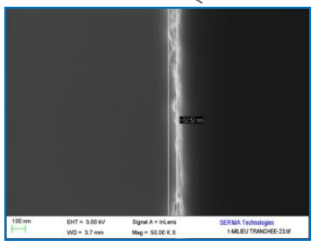
Top

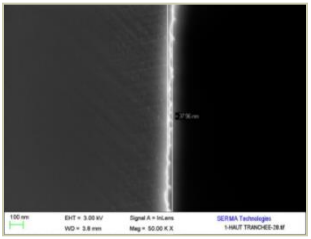
Middle

Bottom

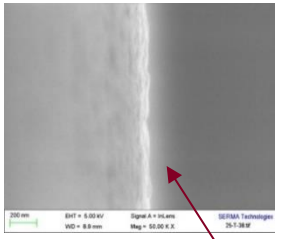
Before HDRF

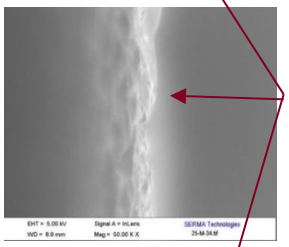


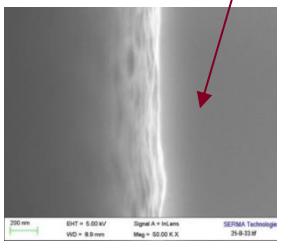




After HDRF







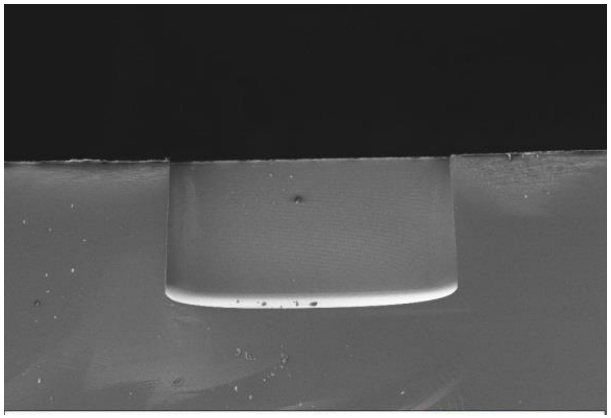
Smooth sidewall

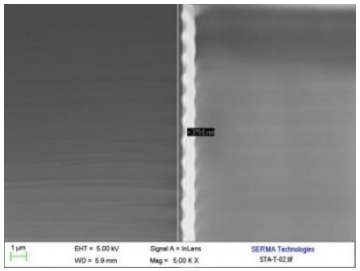
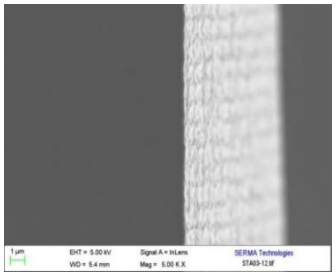
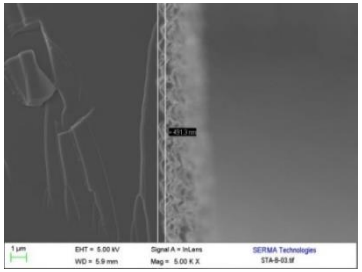
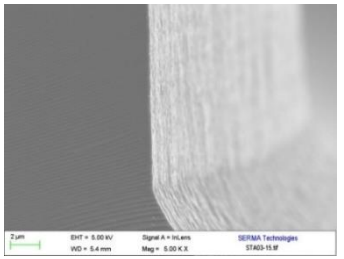
Process time : < 2 minutes

MEMS cavity

DRIE scallops smoothing

600µm wide cavity



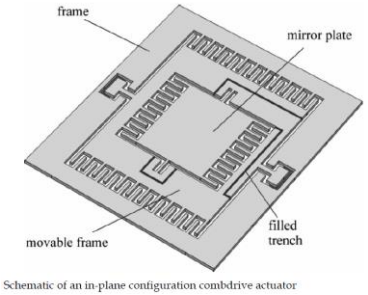
	Before HDRF	After HDRF
Top Scallop 500nm		
Bottom Scallop 400nm		

Process time : < 3 minutes

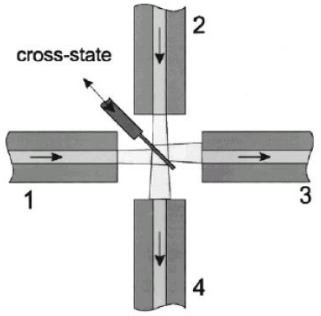
Smoothing scallop improve die to die quality and repeatability

Optical applications

- Benefit of scallop smoothing for optical applications
  - Optical Mems
    - Micro-mirror
    - Optical switch sidewall roughness < 36nm (~0.3dB loss) courtesy IMT Neuchâtel
  - Bio-mems
    - Micro-endoscope head



Micro-mirror



Optical switch

RANKED 1st Suppliers of Fab Equipment RANKED 1st Etch & Clean Equipment
10 BEST Focused Suppliers of Chip Making Equipment
THE BEST Suppliers of Fab Equipment

Summary

- HDRF technology is high plasma density > 1E17 cm^{-3}, mainly O* radicals, no ions bombardment
- Remove Bosch polymer on high aspect ratio structure
- Avoid electrical leaks on TSV, by smoothing sidewall scallops

R&D

Production

Plasma-Therm

Product, Process & Technology Innovation

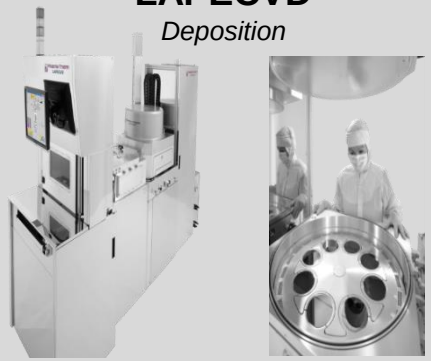
VERSALINE
Etch & Deposition

Micro Die Singulator
Plasma dicing

Odyssey HDRF
Stripping & Cleaning

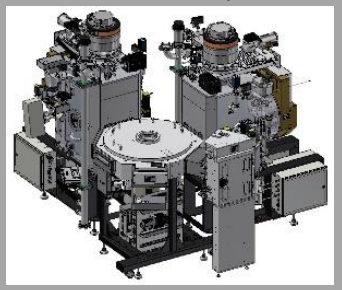
Thank you

LAPECVD
Deposition



Mask Etcher

Pinnacle IBE/IBD
Ion Bean Etch & Deposition



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