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Deposition Control Technology for Arc Ion-Plating Process

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Multi-component ceramic coatings such as TiN, CrN, TiAlN, TiCrN, TiCrSiN and Hard carbon coatings (HCC) were used in wide range of industrial applications, as these have excellent mechanical, chemical and biological properties. These coatings were synthesized by the vapour-phase method from an arc ion plating process. PVD (Physical Vapor Deposition) coating technologies were commonly used in carrying out ceramic coatings, where the coating materials are vaporized from the source and then transported in the form of a vapour through a vacuum or plasma environment to the substrates.

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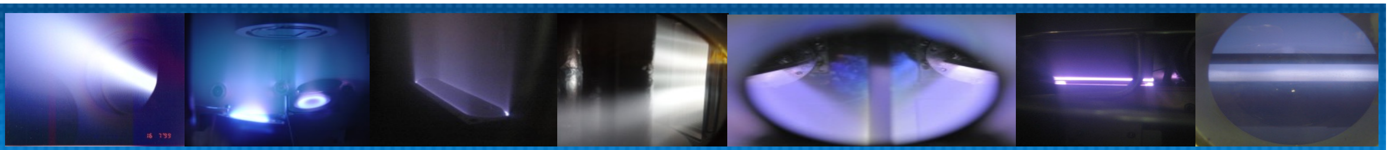
SVC2025 Conference



Deposition Control Technology for Arc Ion-Plating

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Content

Introduction

❖ Current DR Measurement Device : QCM (Quartz Crystal Microbalance)

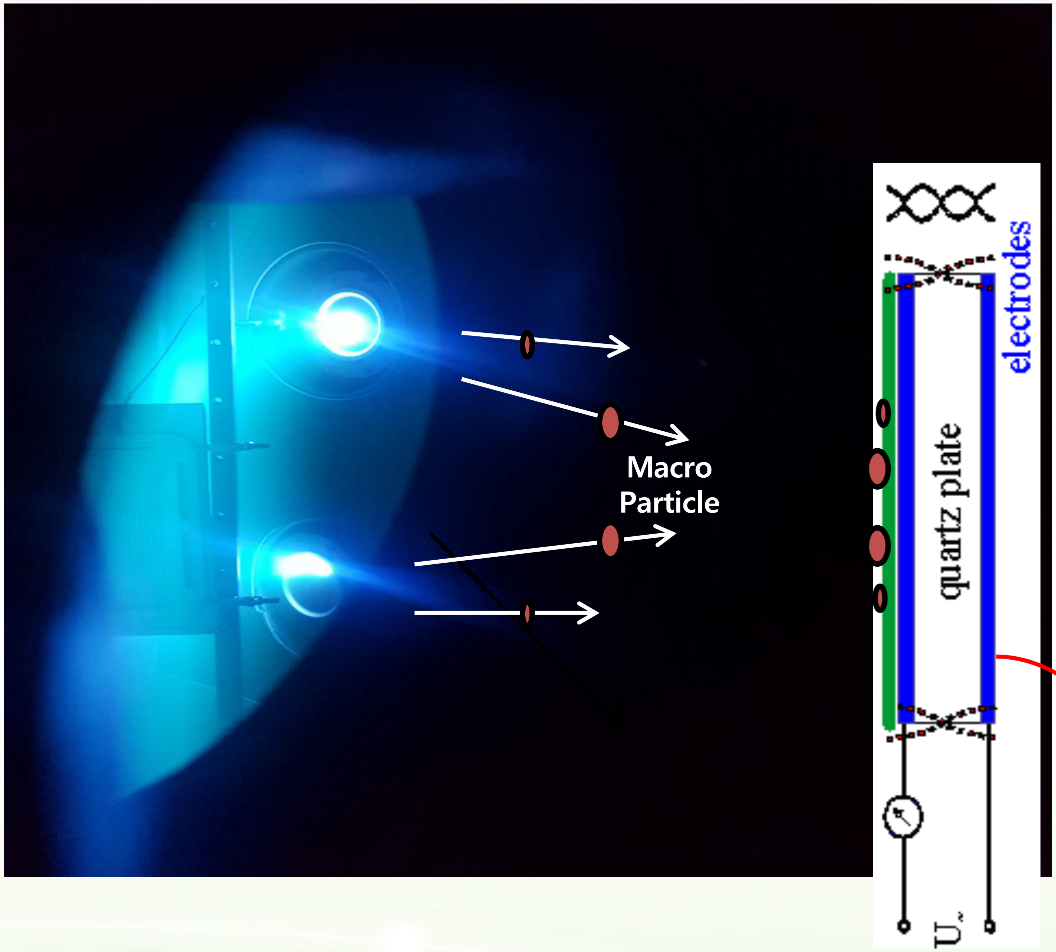
- Mechanism : Measuring the Deposition Rate by Using
  Detecting the Variation of Crystal Resonance
  Depending on Coating Materials
- Advantage : Simple Method for Measuring DR
  Well Establishment of Reference Data
- Disadvantage : Clear Limitation for High Thickness over than 10μm
  Being not Possible to Apply for Arc Ion-plating

New Deposition Rate
Measurement Device

❖ VDM (Vapor Density Measurement) Method

- Mechanism : Measuring Vapor Density → Converting Deposition Rate
- Advantage : No Limitation for Coating Thickness (Ultra Long Life Time),
  Supporting Digital Information for Coating Processes
  (Plasma Status, Variation of Deposition Rate, etc.)
- Disadvantage : Running in the Plasma environment
  Non-establishment of Reference Data
  Risk of Reliability

AIP and QCM



QCM Sensor

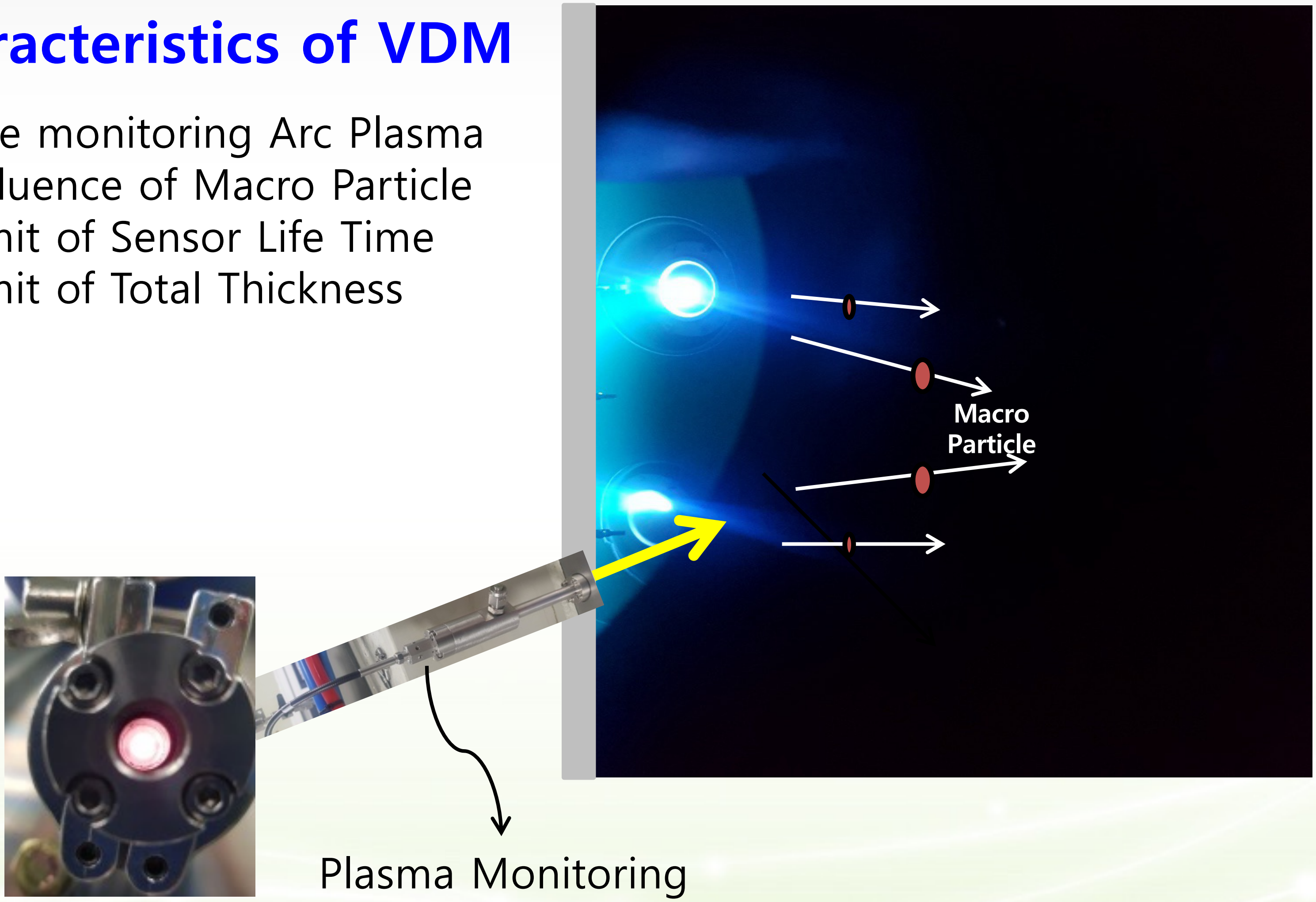
❖Characteristics of AIP

- Using Arc Plasma : Unstable
- Fast Growth Rate : 5nm/sec
- High Quality of Coating Layer
- Generation of Macro Particles
- Limitation of DR Control
- QCM Life Time : ≤10min

AIP and VDM (Vapor Density Measurement)

❖ Characteristics of VDM

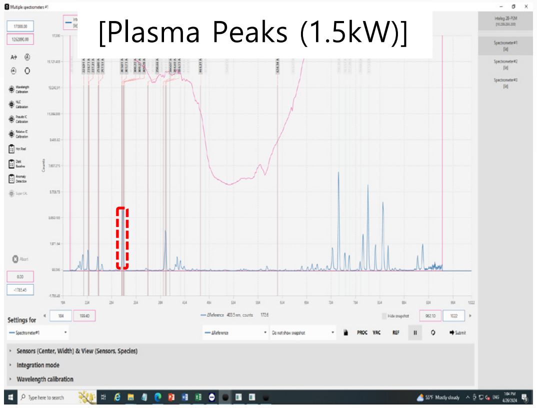
- Remote monitoring Arc Plasma
- No Influence of Macro Particle
- No Limit of Sensor Life Time
- No Limit of Total Thickness

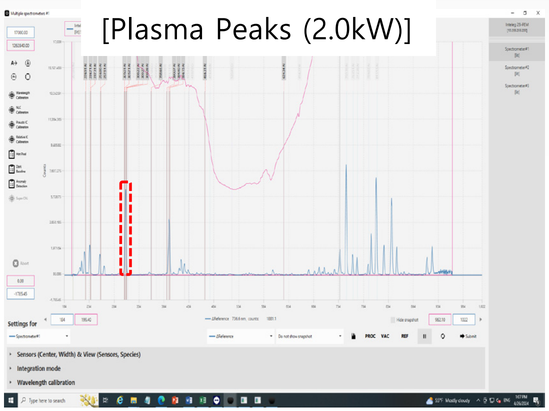


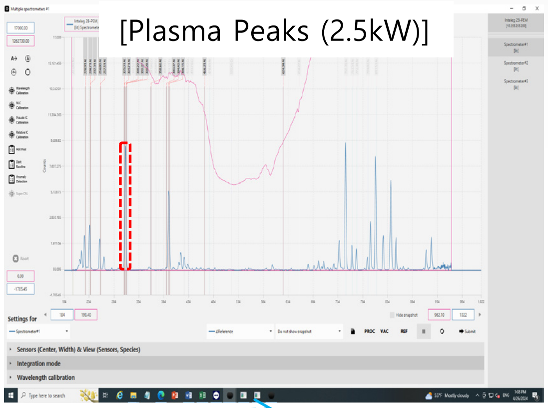
Plasma Monitoring
Sensor

Mechanism of VDM

❖ Coating Process : Al coating

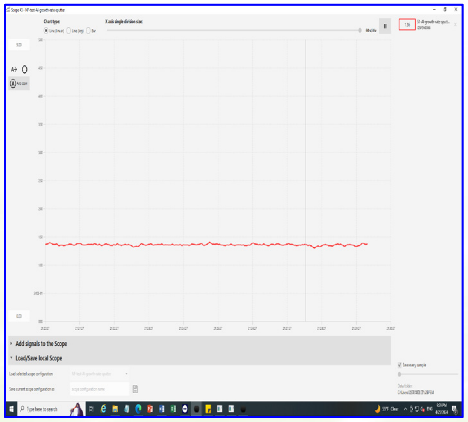

[Plasma Peaks (1.5kW)]


[Plasma Peaks (2.0kW)]


[Plasma Peaks (2.5kW)]

[Vapor Density vs. Plasma Power]

$$\mathrm{DR} = \alpha \cdot f_{(\mathrm{VD})}$$

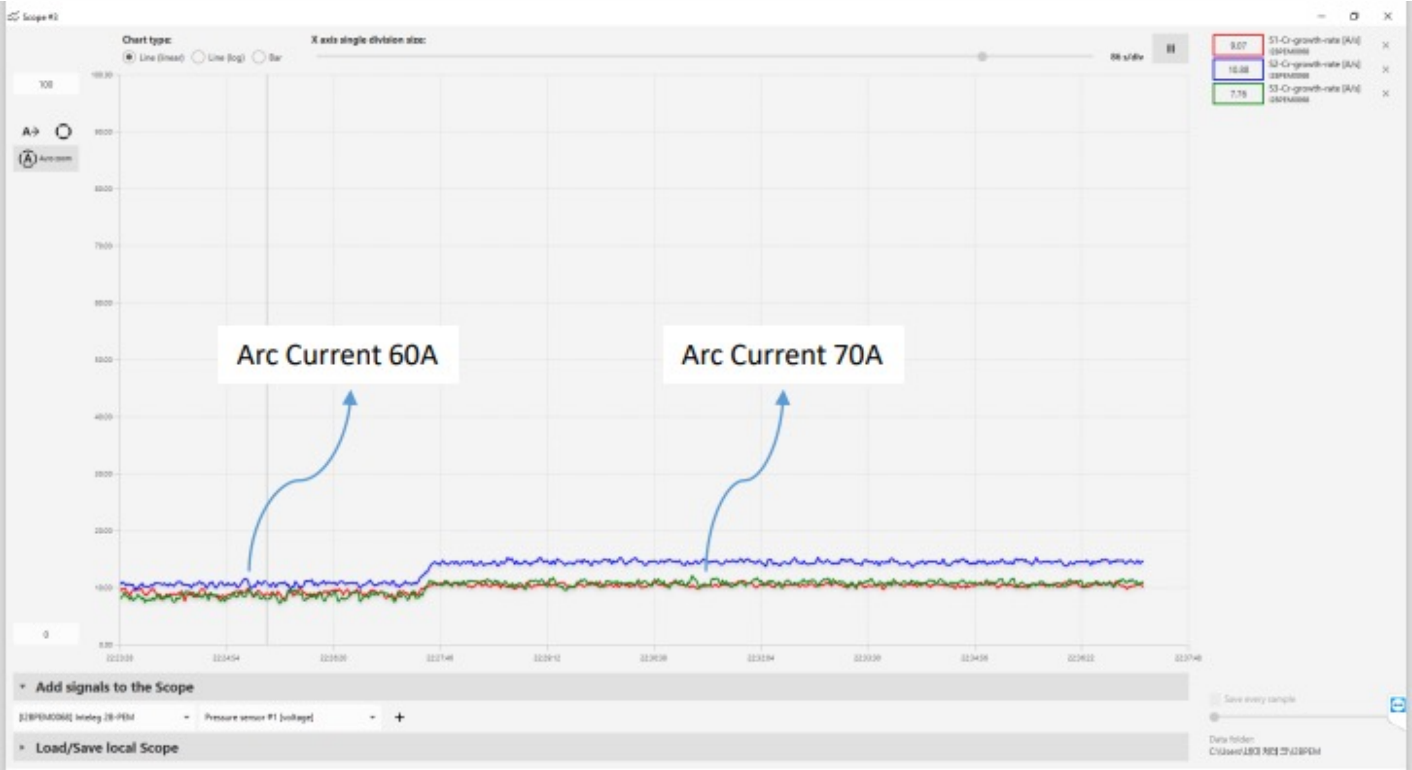


[Deposition Rate]

Mechanism of VDM (AIP)

❖ Measuring Deposition Rate

- Choosing the very unique peak
- Measuring Vapor Density
- Converting Deposition Rate

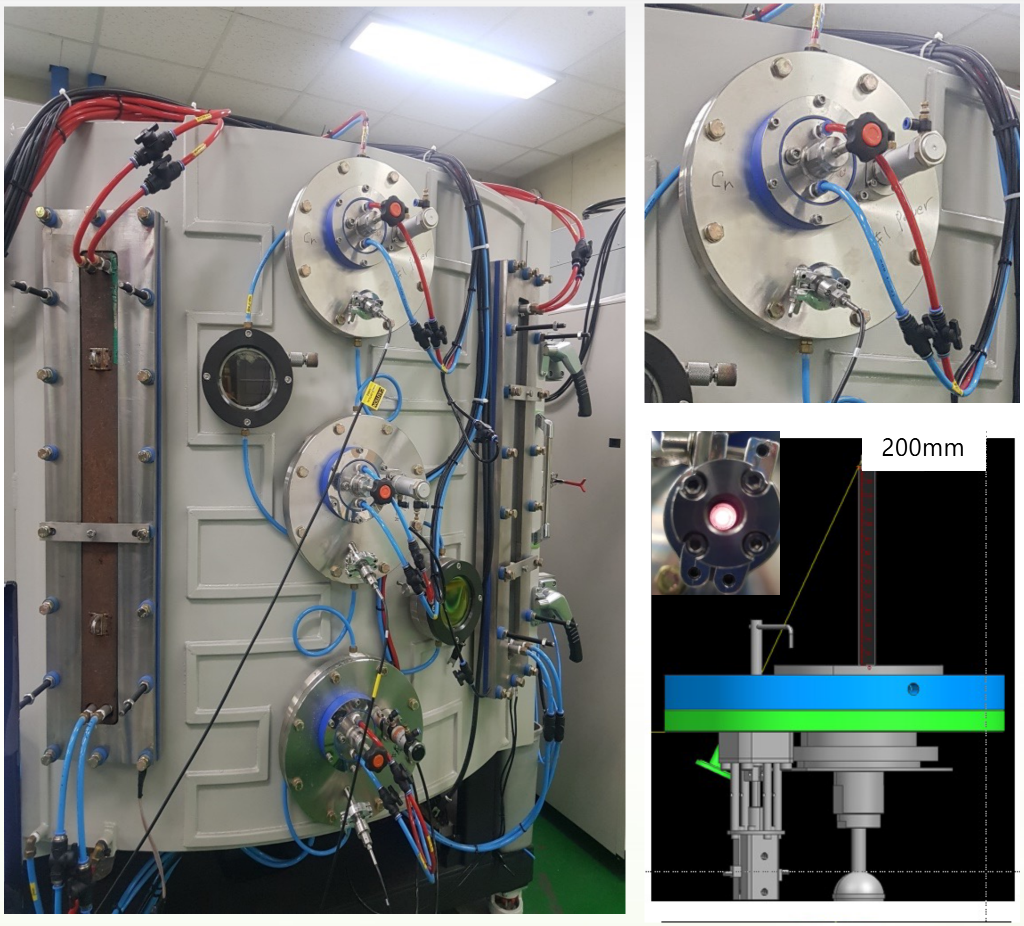


Arc Current 60A

Arc Current 70A

Equipment (AIP)

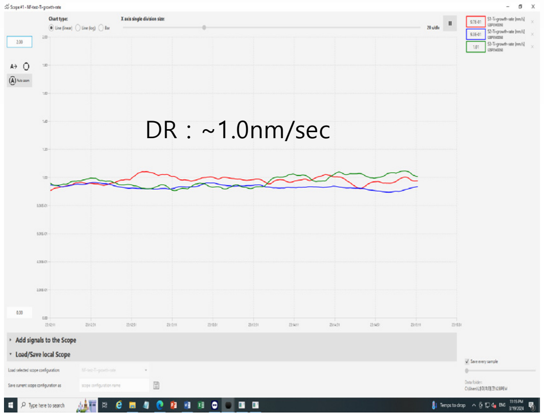
[AIP System]



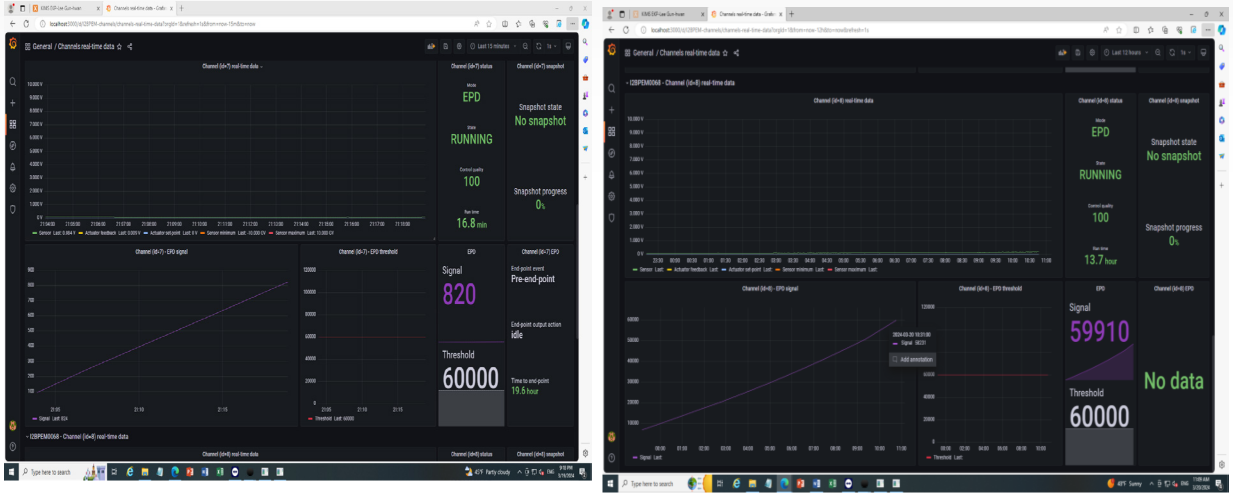
[Configuration of Arc Source]

Measuring Deposition Rate (Ti)

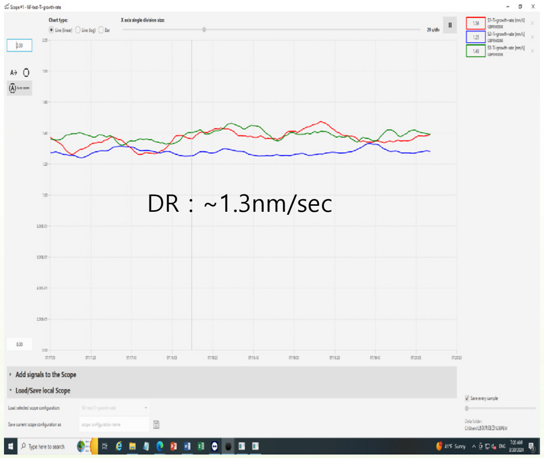
❖ Measuring Deposition Rate of Ti Arc Ionplating Process



DR : ~1.0nm/sec



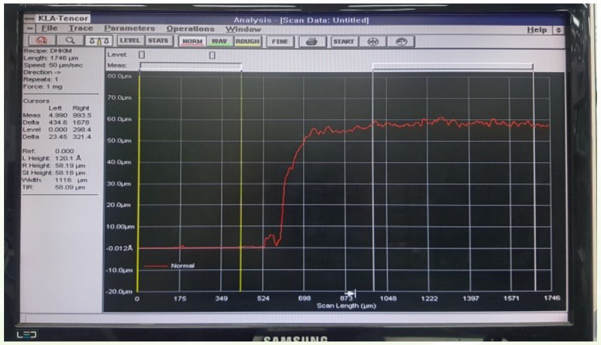
[VDM Thickness Data]



DR : ~1.3nm/sec

❖ DR of Ti Arc Ionplating

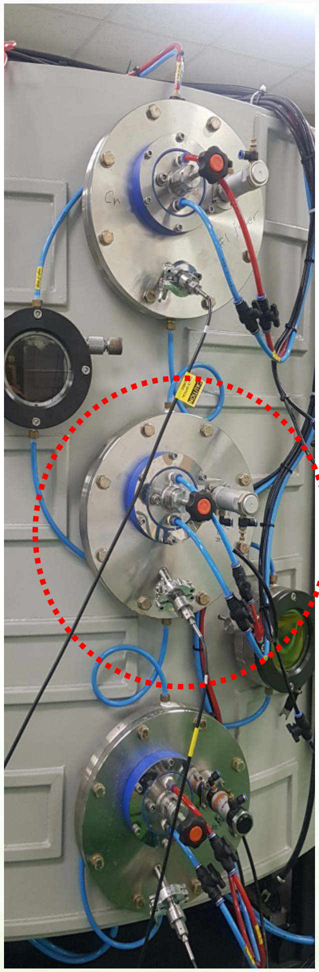
- Applied Current : 60A
- DR : ~1.2nm/sec
- TT by VDM : 60μm
- Coating Time : 13.7hrs
- TT by α-step : 58.2μm

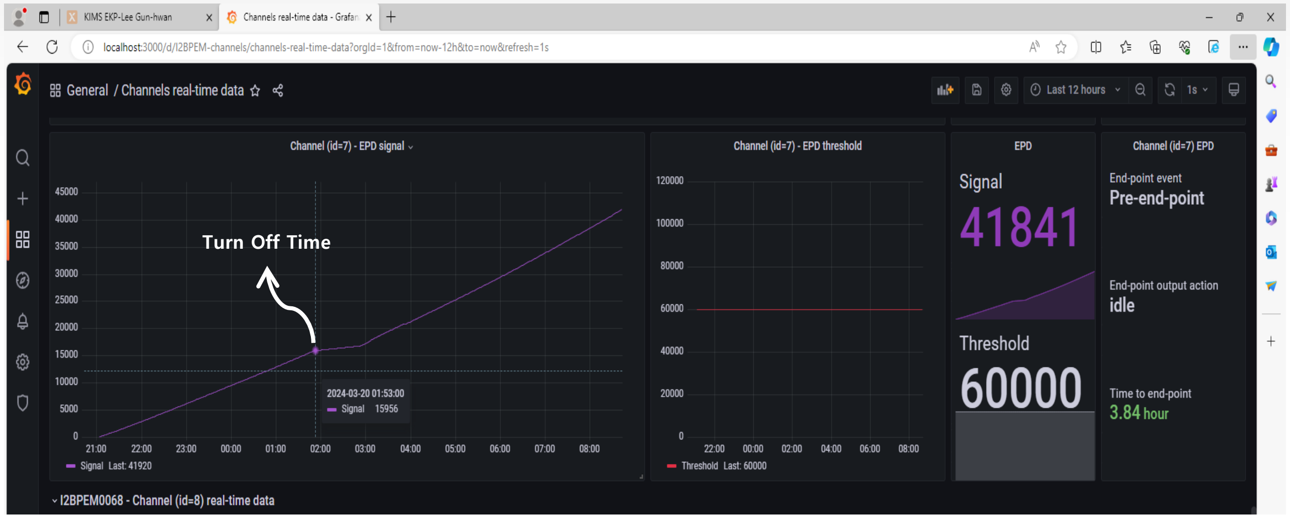


[α-step Thickness Data]

Measuring Deposition Rate (Ti)

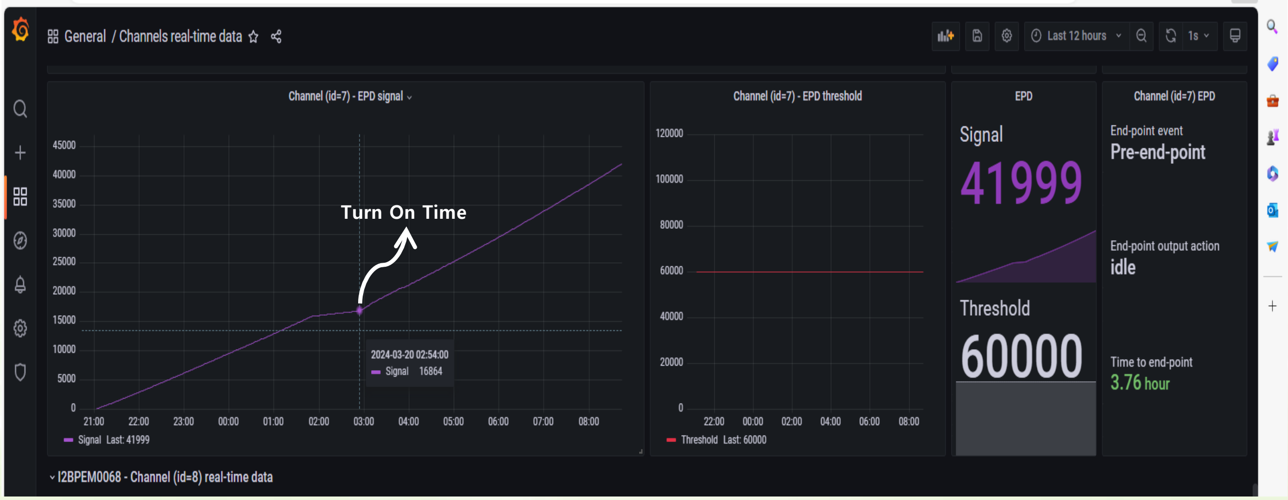
❖ Supplying Digital Data for Total Process





Turn Off Time

Middle Arc Source Monitoring Data

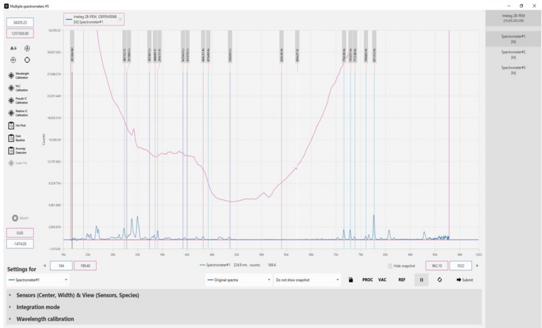


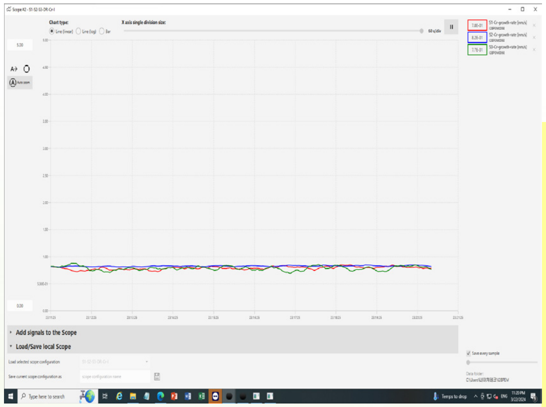
Turn On Time

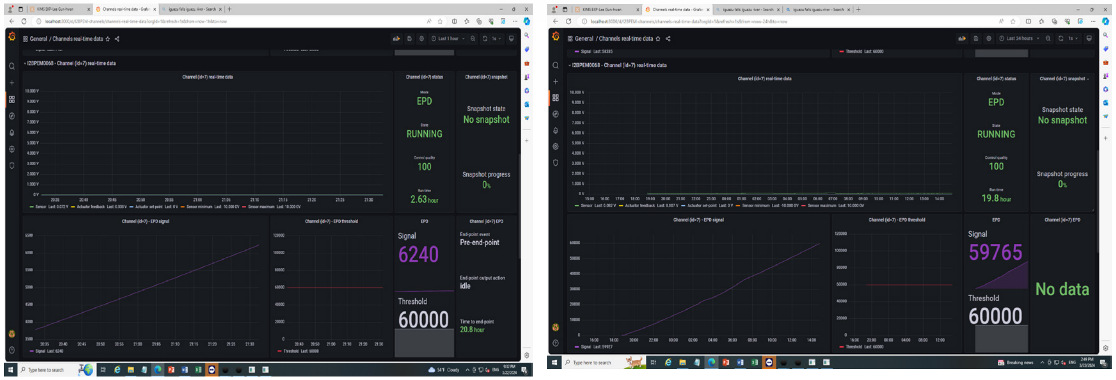
Measuring Deposition Rate (Cr)

❖ Selecting the Plasma Peak

- Choosing the very unique peak
- Sufficient Intensity Change







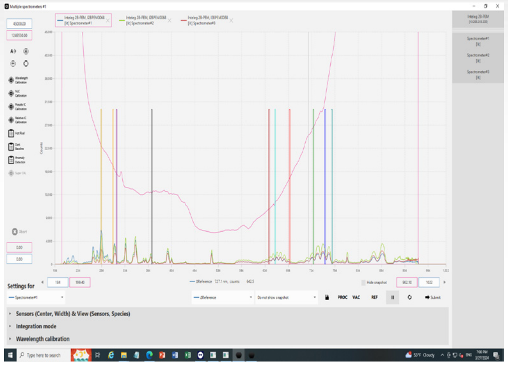
[VDM Thickness Data]

❖ DR of Cr Arc Ionplating

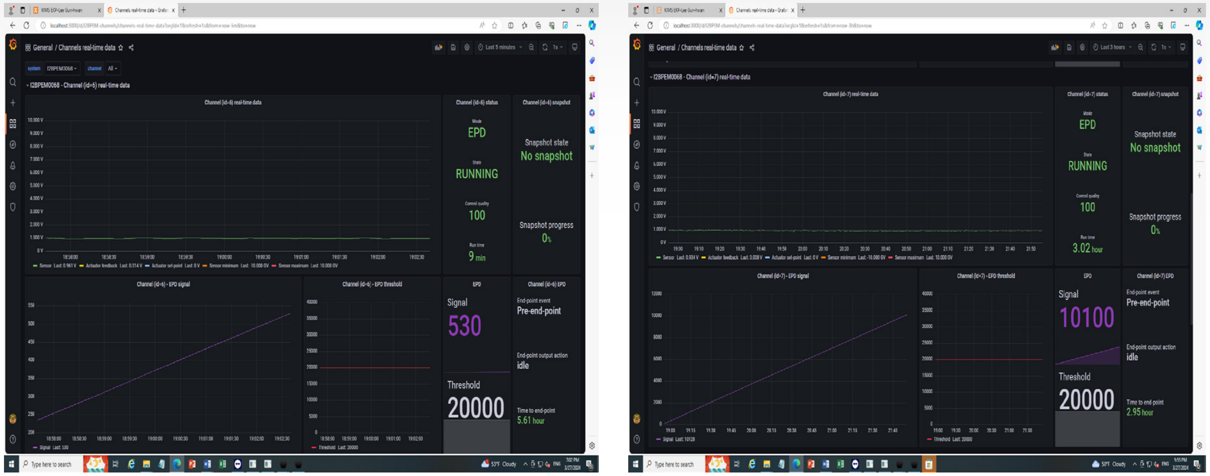
- Applied Current : 60A
- DR : ~0.83nm/sec
- TT by VDM : 60μm
- Coating Time : 19.9 hrs
- TT by α-step : 56.2μm

[α-step Thickness Data]

Measuring Deposition Rate (CrN)



[CrN Plasma Peaks]



Channel (id=6) status
Mode: EPD
State: RUNNING
Control quality: 100
Run time: 9 min

Channel (id=6) snapshot
Snapshot state: No snapshot
Snapshot progress: 0%

EPD
Signal: 530
Threshold: 20000

Channel (id=6) EPD
End-point event: Pre-end-point
End-point output action: idle
Time to end-point: 5.61 hour

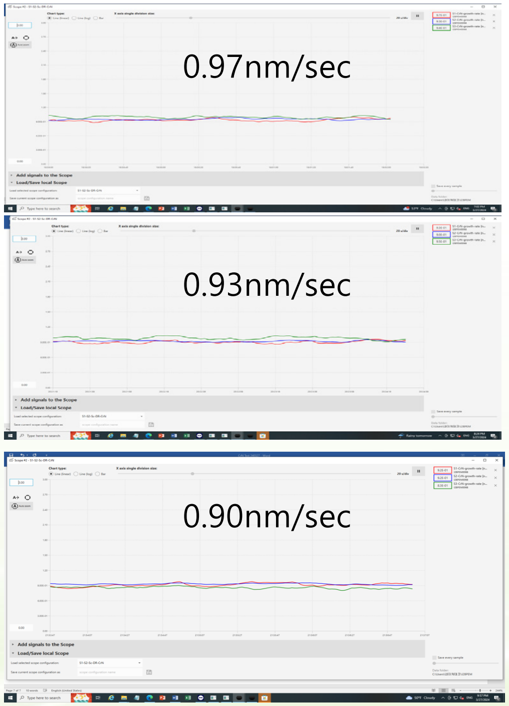
Channel (id=7) status
Mode: EPD
State: RUNNING
Control quality: 100
Run time: 3.02 hour

Channel (id=7) snapshot
Snapshot state: No snapshot
Snapshot progress: 0%

EPD
Signal: 10100
Threshold: 20000

Channel (id=7) EPD
End-point event: Pre-end-point
End-point output action: idle
Time to end-point: 2.95 hour

[VDM Thickness Data]



0.97nm/sec

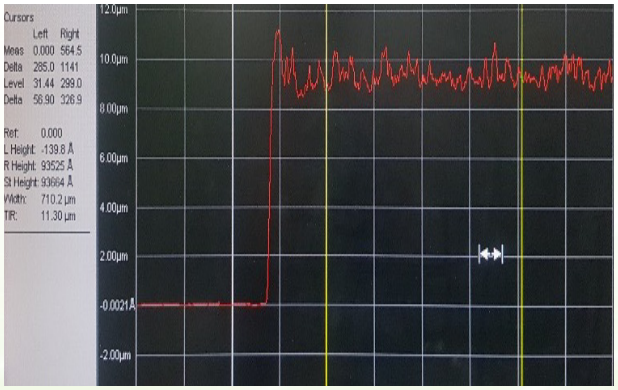
0.93nm/sec

0.90nm/sec

[Deposition Rate Data]

❖ DR of CrN Arc Ionplating

- Applied Current : 65A
- DR : ~0.97nm/sec ~ 0.9nm/sec
- TT by VDM : 10µm
- Coating Time : 3.02hrs
- TT by α-step : 9.3µm



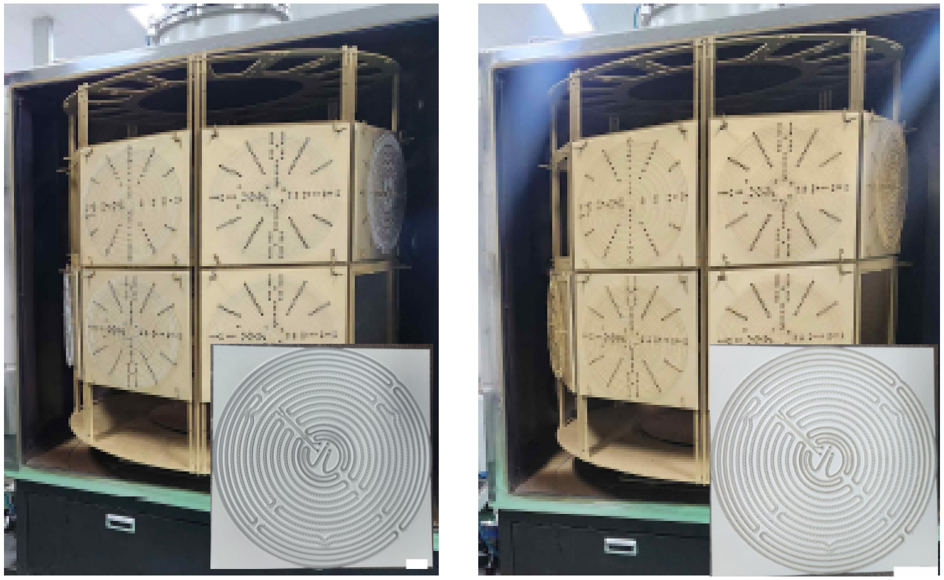
Cursors

	Left	Right
Meas	0.000	564.5
Delta	285.0	1141
Level	31.44	299.0
Delta	56.90	326.9

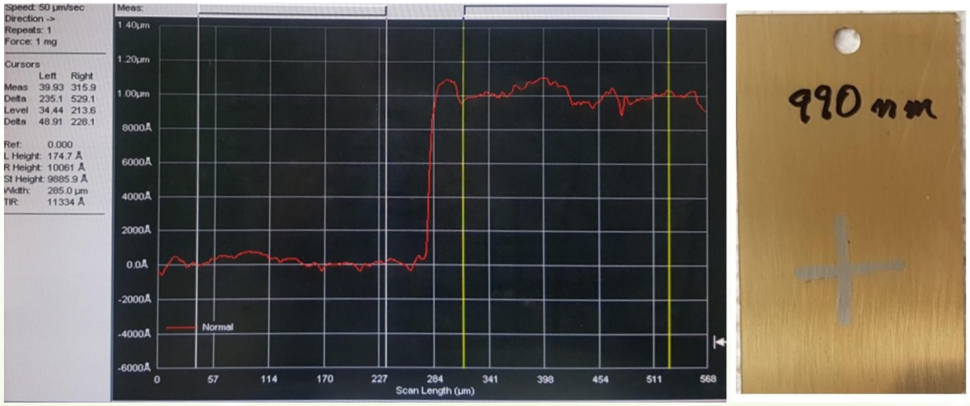
Ref: 0.000
L Height: -139.8 Å
R Height: 93525 Å
St Height: 93664 Å
Width: 710.2 µm
TIR: 11.30 µm

[α-step Thickness Data]

Industrial Application



- ❖ **Product : TiN coating on Coil Heating Element**
- Coating Thickness : 1000nm±10%
- Process Error Rate : ≥15%
- **Trying to apply VDM for Process Control**

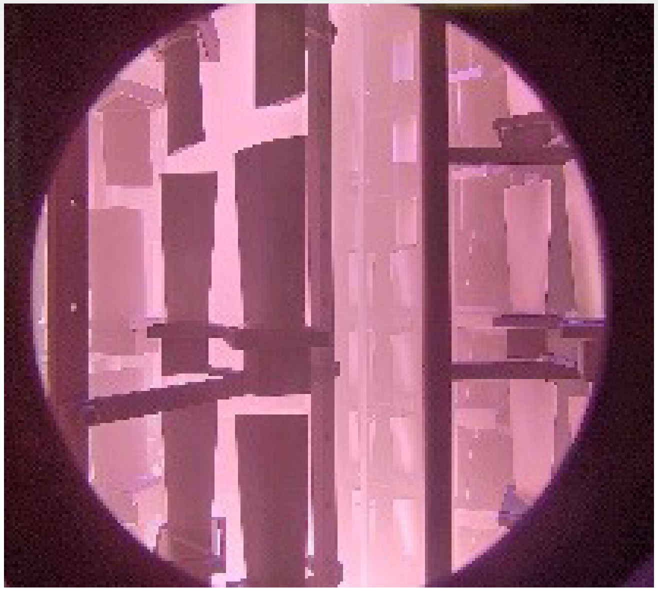


```
Speed: 50 µm/sec
Direction ->
Repeats: 1
Force: 1 mg

Cursors
        Left    Right
Meas    39.93   315.9
Delta   235.1   529.1
Level   34.44   213.6
Delta   48.91   228.1

Ref:        0.000
L Height:   174.7 Å
R Height:   10061 Å
St Height:  9885.9 Å
Width:      285.0 µm
TIR:        11334 Å
```

[Thickness Control by α-step]

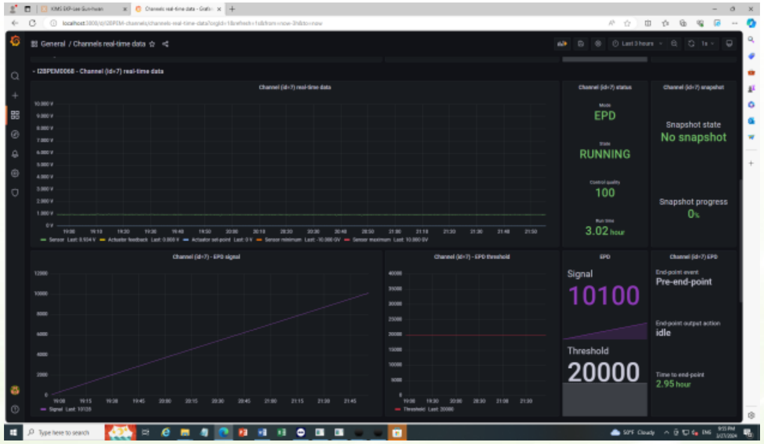
Industrial Application

KIMS



❖ **Product : CrN coating on Turbine Blade**

- Coating Thickness : 10μm ±15%
- Process Error Rate : ≥20%
- **Trying to apply VDM for Process Control**



General / Channels real-time data

Mode: EPD

State: RUNNING

Control quality: 100

Run time: 3.02 hour

Snapshot state: No snapshot

Snapshot progress: 0%

Signal: 10100

Threshold: 20000

End-point event: Pre-end-point

End-point output action: idle

Time to end-point: 2.95 hour

[Thickness Control by VDM]

Conclusions

✓ VDM Method enables:

- Establishing stable Arc processes in an industrial-size coater : Thickness control quality factor >93% at all times
- Establishing the new method of deposition rate control for Arc ion plating
- Confirming that VDM is Working Very Well in Arc Ion-plating

✓ Next Step

- **Increasing the Reliability of VDM Method**
  - Accumulating Various Experimental Data
  - Developing More Proper Relationship between VD and DR
- **Conducting Industrial Applications**