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Characterization of Ultra High Temperature Ceramic Coatings Deposited by Vacuum Plasma Spraying

Diletta Sciti
UHTCMCs: short vs continuous fibers, Italy

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Contents

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Introduction

- Materials for Extreme Environment Applications
- UHTC Coatings
- Thermal Spraying & Vacuum Plasma Spraying

Experimental

Results and Discussion

- Properties of TaC Coatings Deposited by Vacuum Plasma Spraying at Various Condition
- Properties of HfC Coatings Deposited by Vacuum Plasma Spraying at Various Condition

Summary

Introduction

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Materials for Extreme Environment Applications

Refractory Metals

- High temperature strength
- Good wear & erosion resistance
- Low oxidation resistance
- High density
- High cost

Carbon

- High mechanical strength
- Highest melting temperature
- Low density
- Vulnerable to oxidation at low temperature

Ceramic Matrix Composites (SiC)

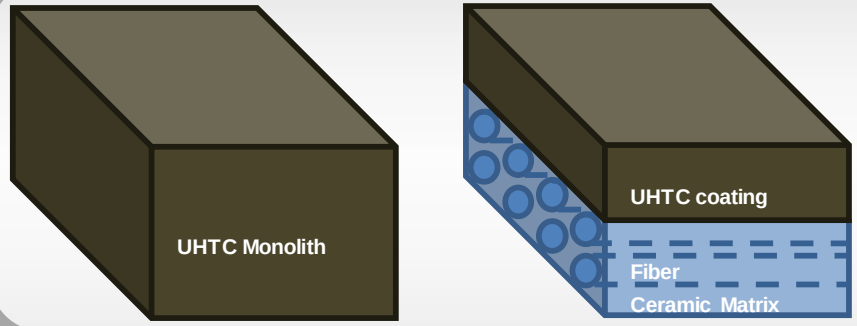
- High mechanical strength
- High oxidation resistance below 1700 ºC (Formation of SiO_2 glass on the surface)
- Low density

Ultra High Temperature Ceramics

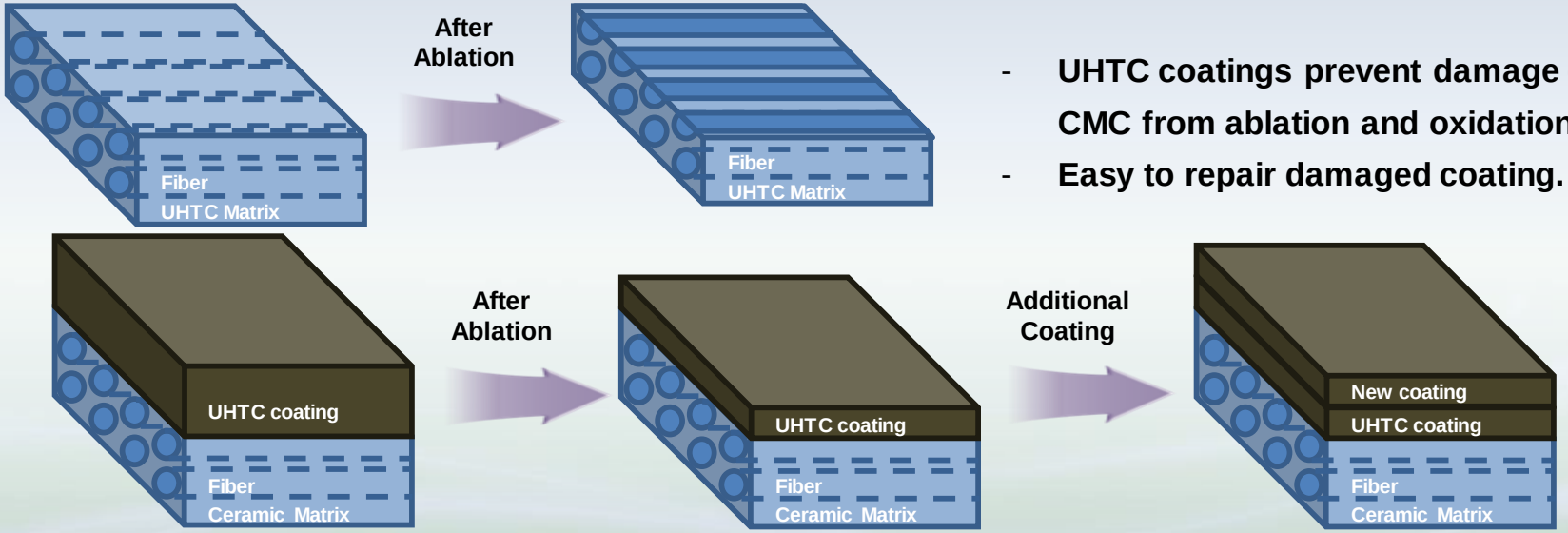
- High melting temperature (up to 3000 ºC)
- Good chemical stability at high temperature
- Easily oxidized
- High density

Introduction

Why UHTC Coatings?



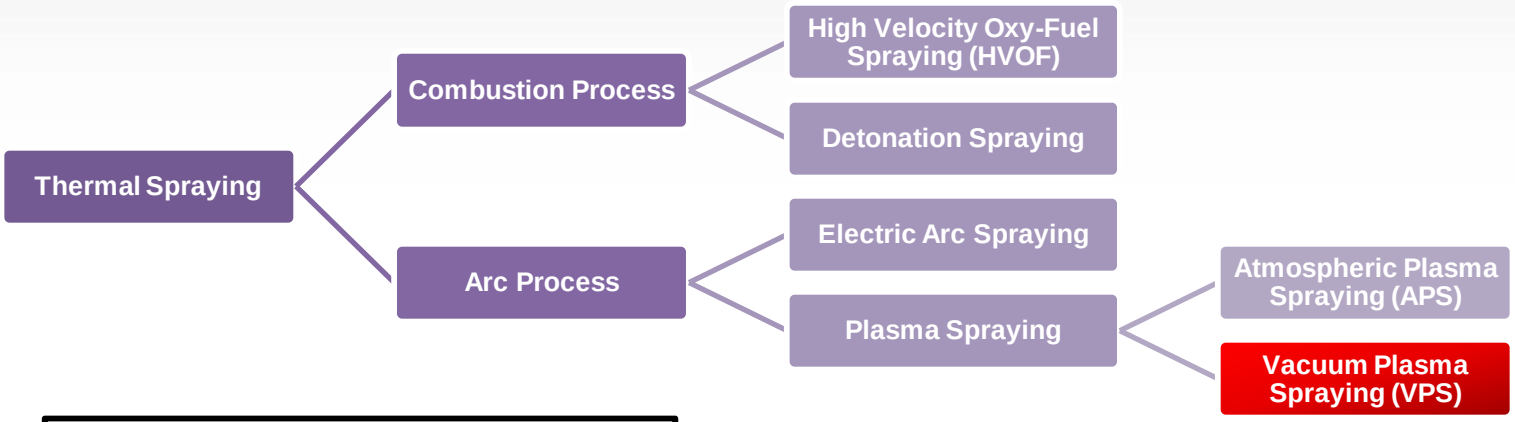
- UHTC monoliths weigh too much because of their high density.
- UHTC coatings can reduce the weight.

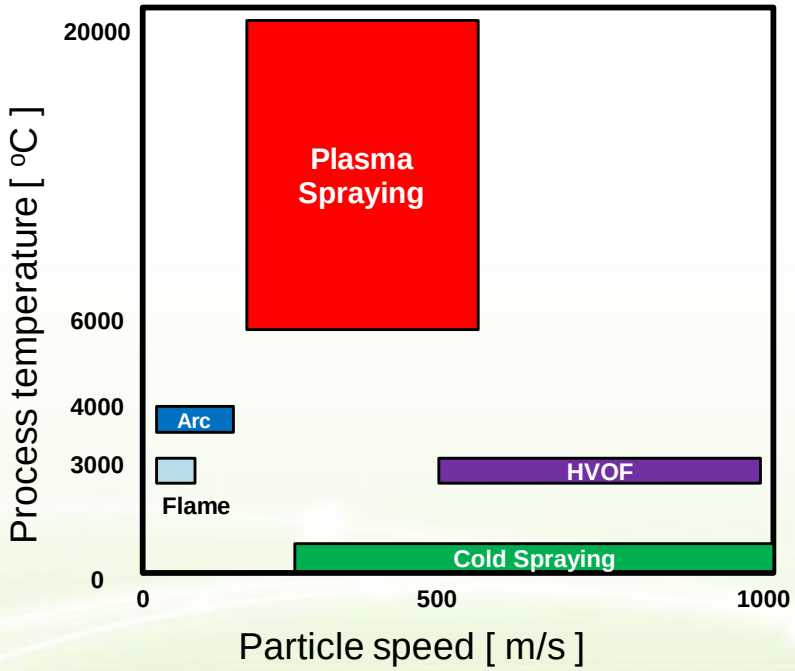


- UHTC coatings prevent damage of CMC from ablation and oxidation.
- Easy to repair damaged coating.

Introduction

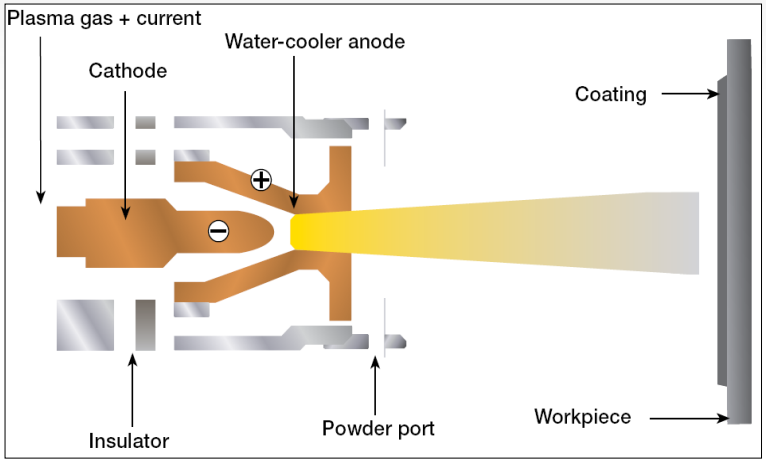
What Is Thermal Spraying?

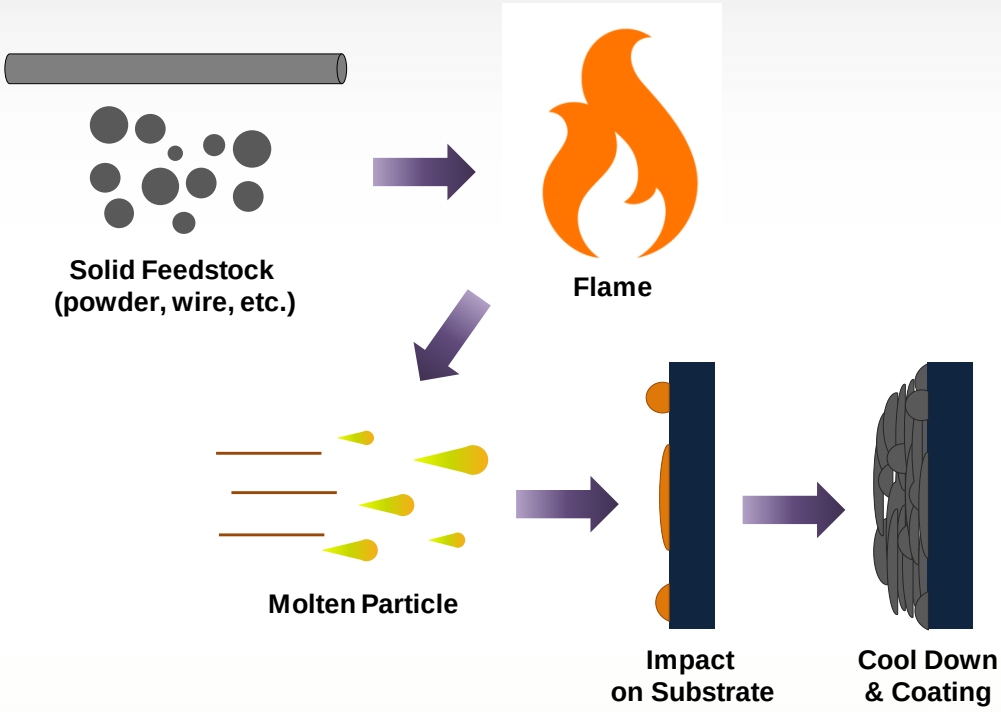


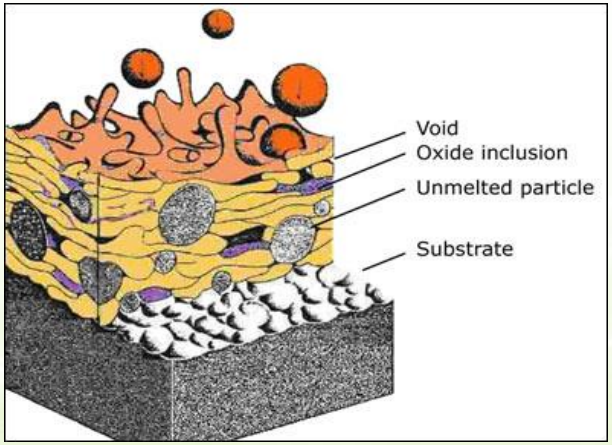


Introduction

Vacuum Plasma Spraying (VPS)



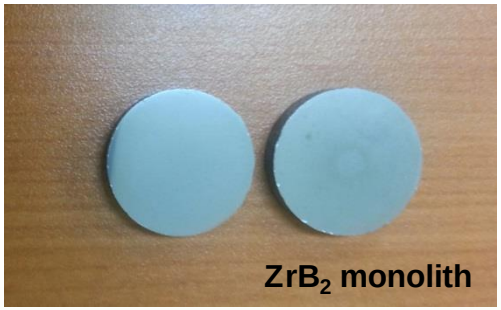




Experimental

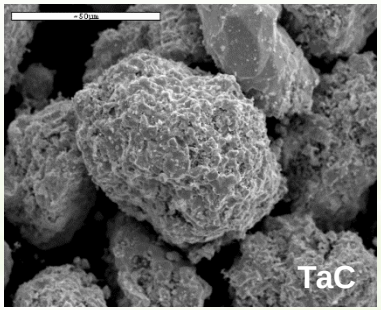
- Plasma Flame Conditions

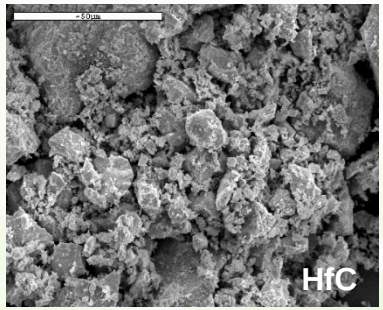
- Primary gas : Ar
- Secondary gas : H_2
- Ar to H_2 ratio : 10 to 3
- Atmosphere gas : N_2



- Experimental Conditions

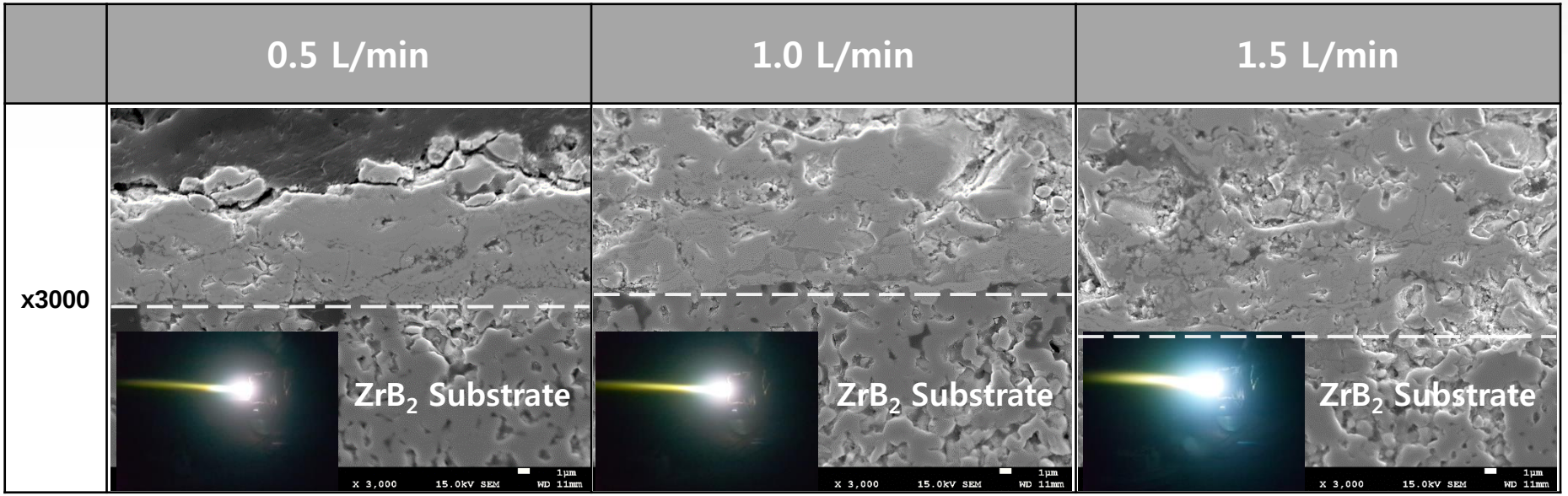
- Feeding powder : TaC and HfC powders (size distributed)
- Substrate : Sintered ZrB_2 monolith
- Various working pressure
- Various carrier gas flow

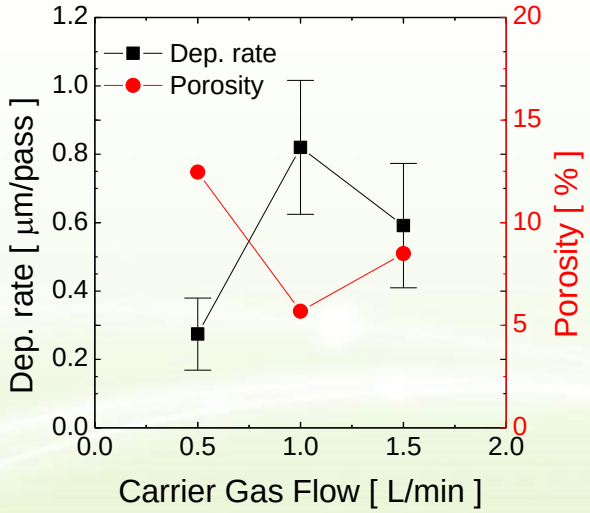




Results

Microstructure of TaC Coatings at Various Carrier Gas Flow



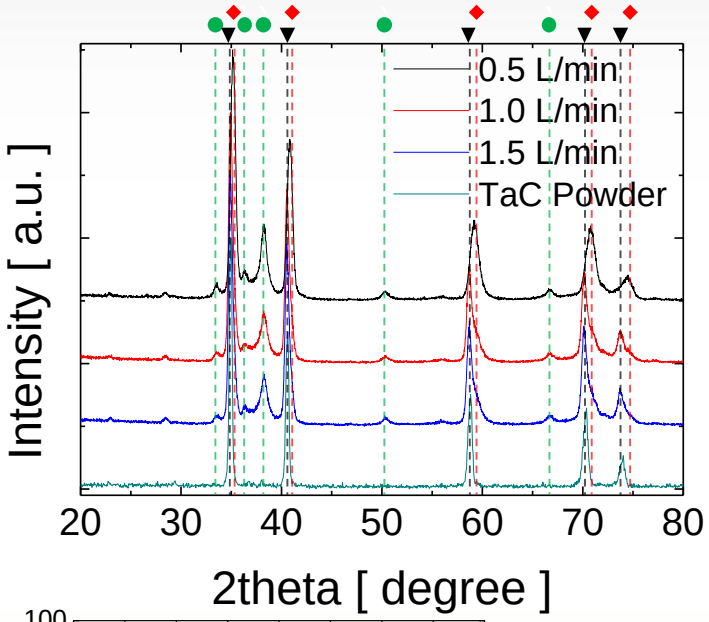


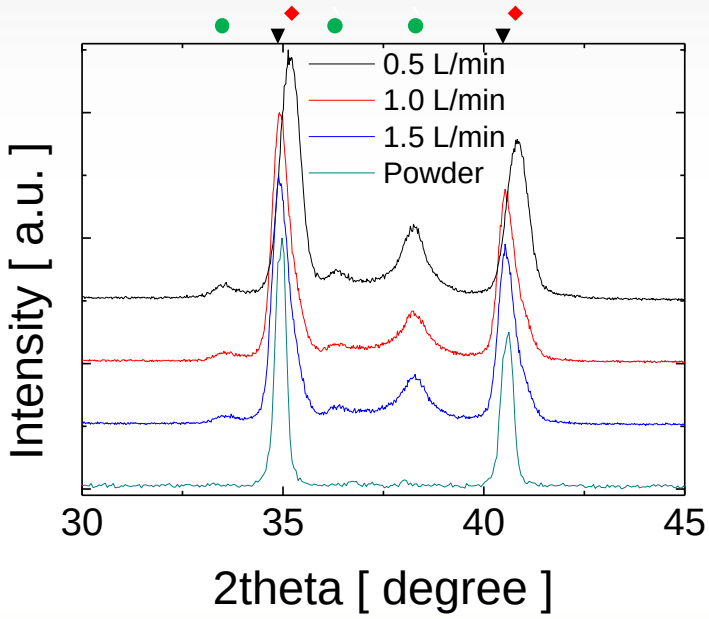
- Working pressure – 150 mbar

- TaC coatings adhered well to surface of ZrB_2 substrates.
- The highest deposition rate and lowest porosity TaC coating was obtained through proper carrier gas flow level.

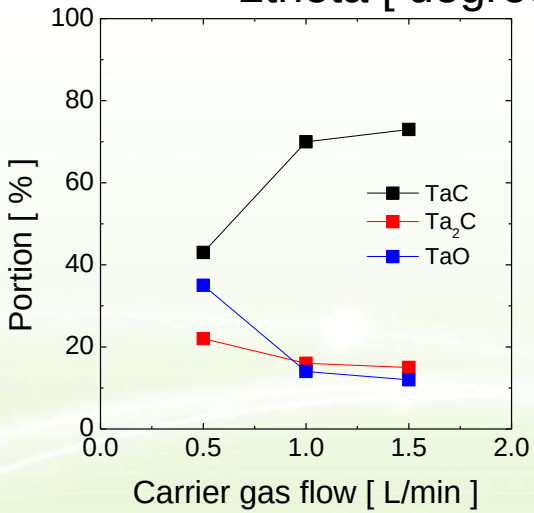
Results

Crystal Structure of TaC Coatings at Various Carrier Gas Flow





TaO
Ta_2C
TaC



- Decarbonization of TaC occurred during plasma spraying.
- TaO formed during spraying.
- Oxidation of TaC occurred well when carrier gas flow level was not enough for injecting powders into the flame.

Results

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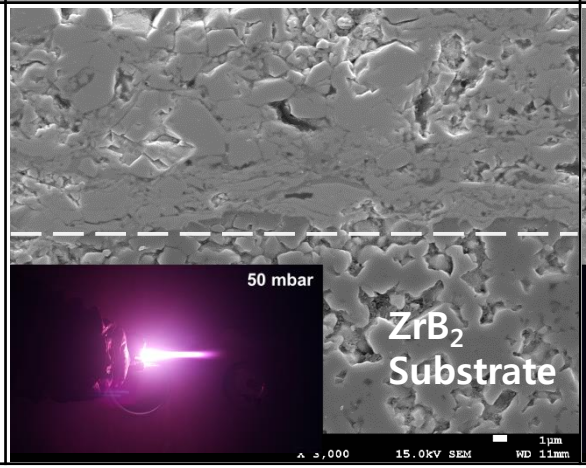
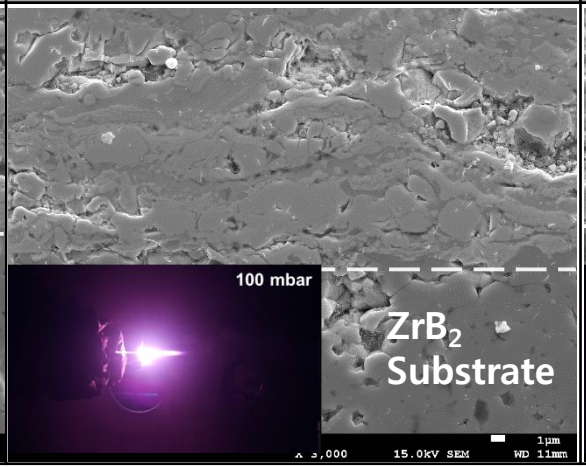
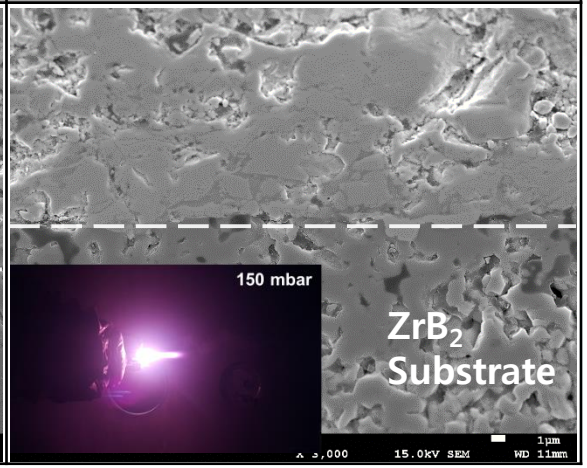
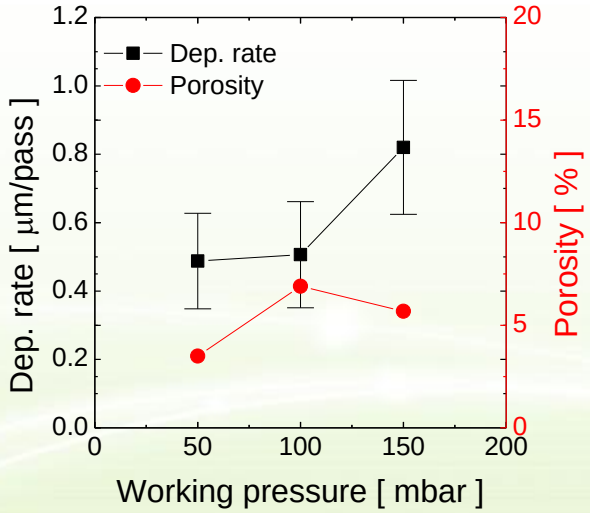
Microstructure of TaC Coatings at Various Working Pressure

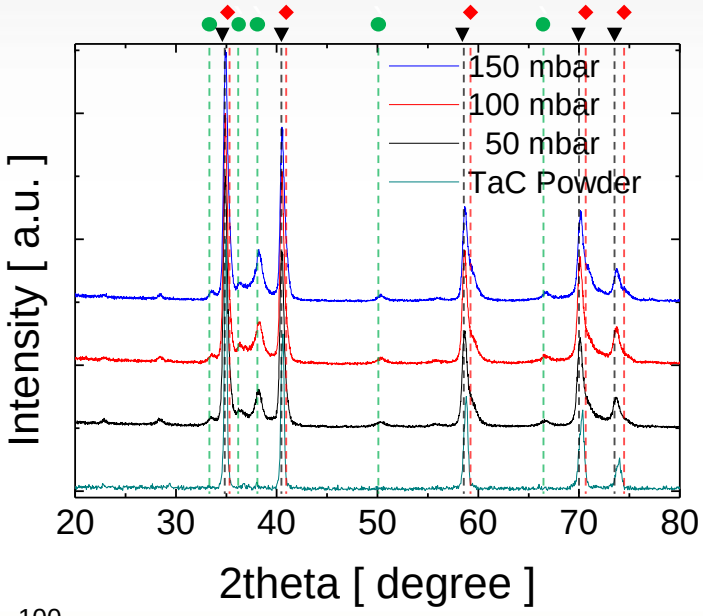
	50 mbar	100 mbar	150 mbar
x3000			

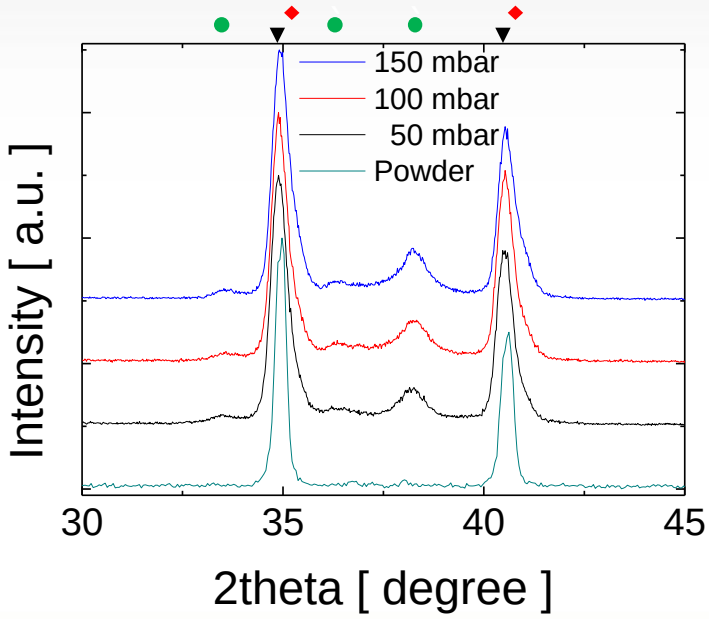


- As changing working pressure, the shape of plasma flame changes.
- Flatter splats were deposited in lower working pressure because of bigger plasma flame.

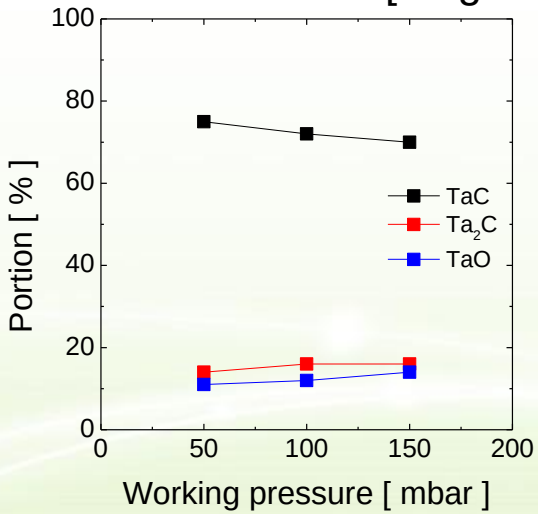
Results

Crystal Structure of TaC Coatings at Various Working Pressure





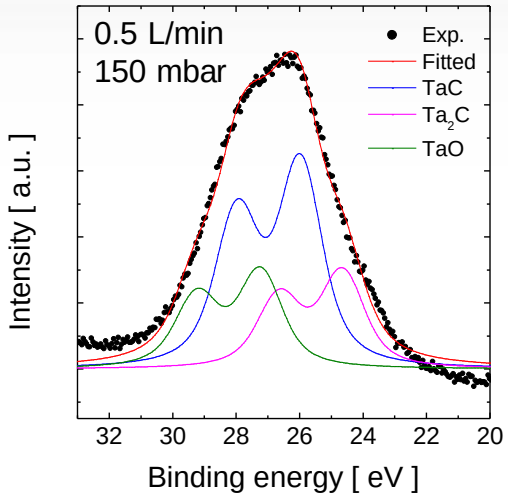
TaO
Ta_2C
TaC

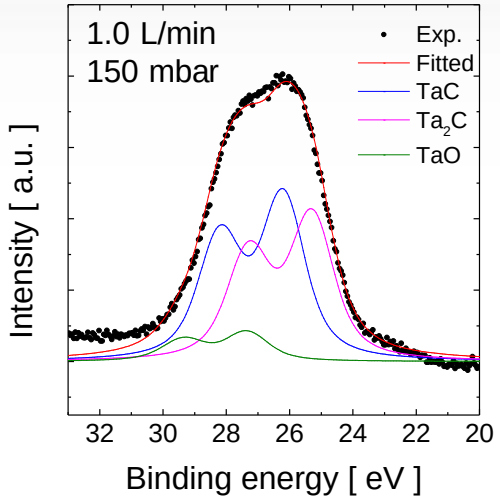


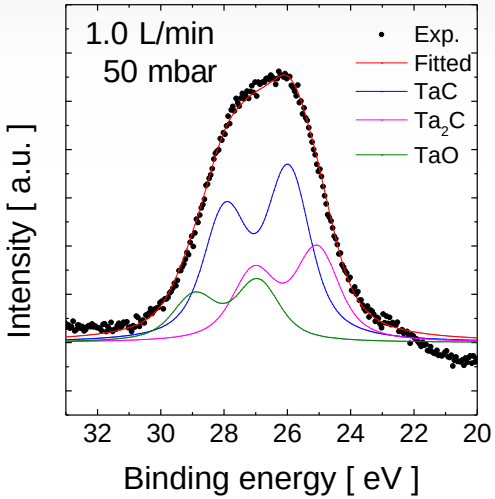
- Content of TaC slightly increased as decreasing the working pressure.

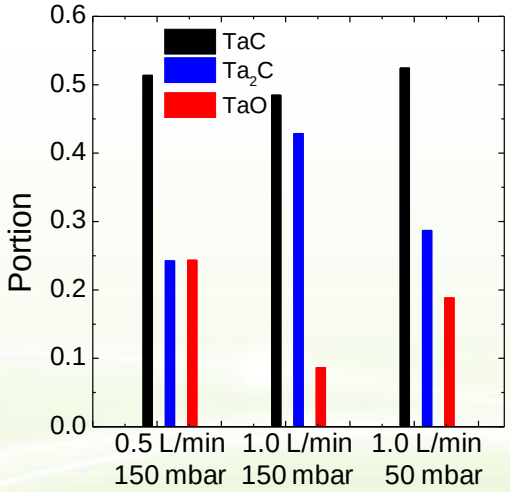
Results

XPS analysis of TaC Coatings





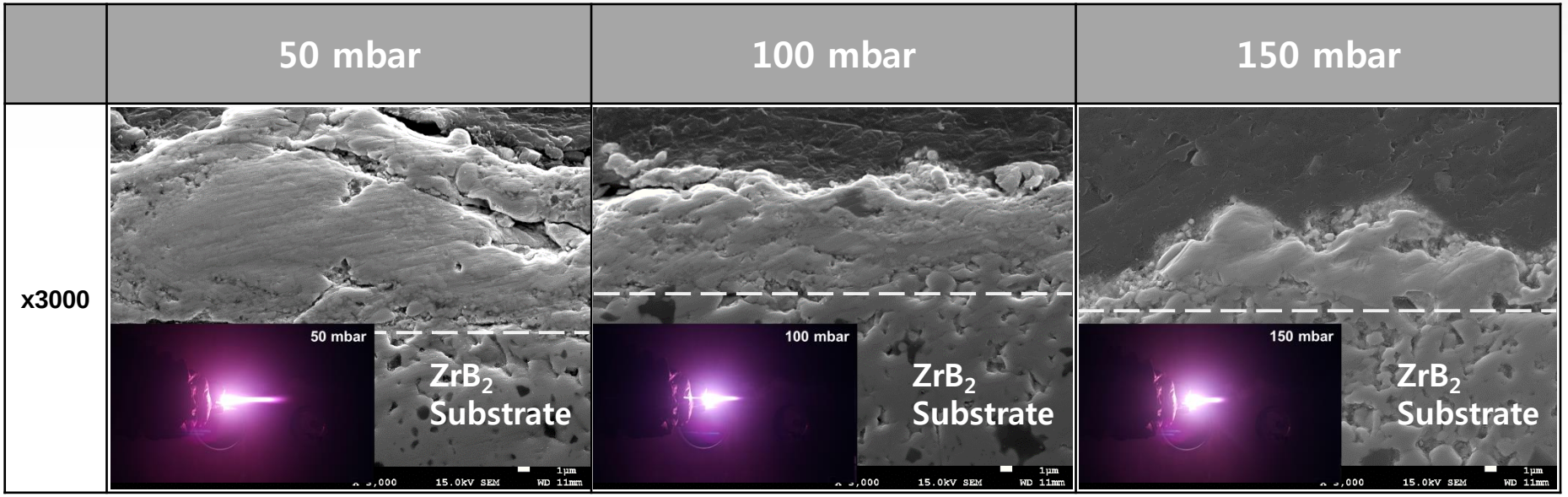


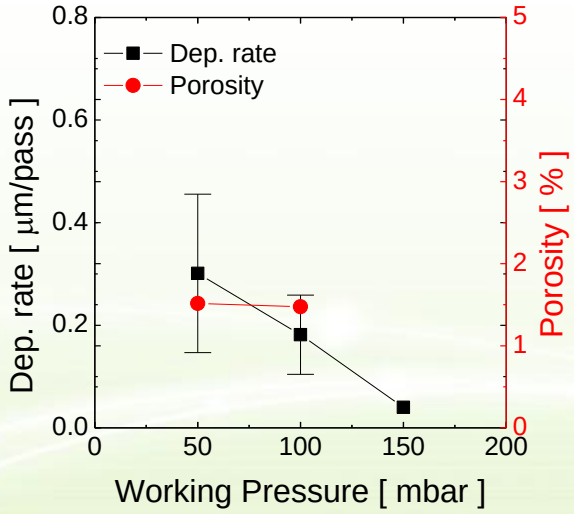


- Same as XRD analysis, the portion of TaO decreased when powders are injected into the plasma flame.
- Portion of Ta_2C decreased when working pressure decreased.

Results

Microstructure of HfC Coatings at Various Working Pressure



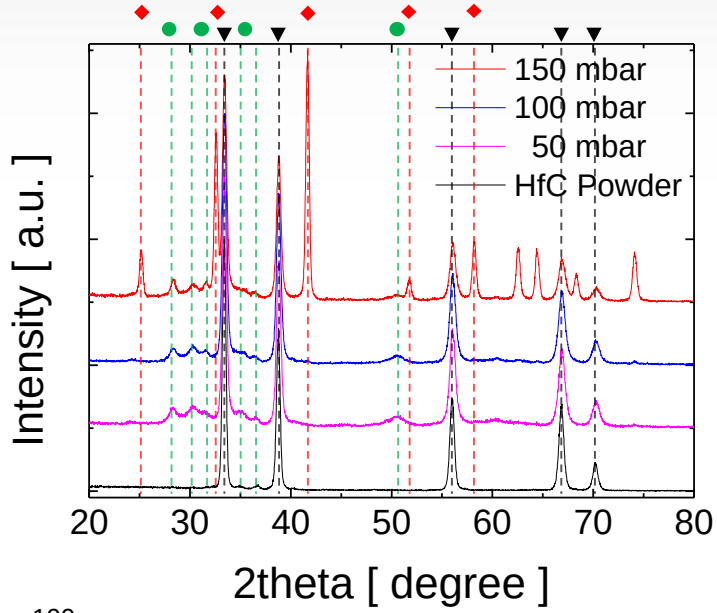


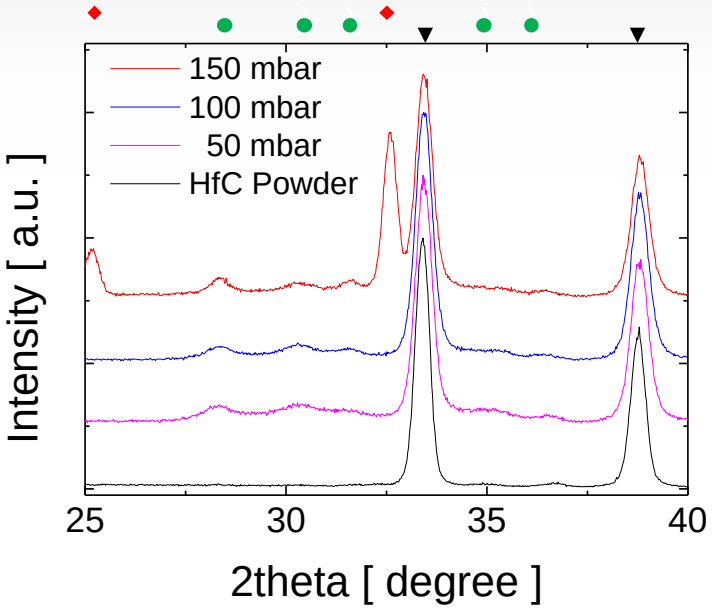
- Carrier gas flow – 0.6 L/min

- As increasing the working pressure during HfC spraying, the coating thickness decreased.
- The deposition rate and porosity of HfC coatings decreased compared to TaC coatings.

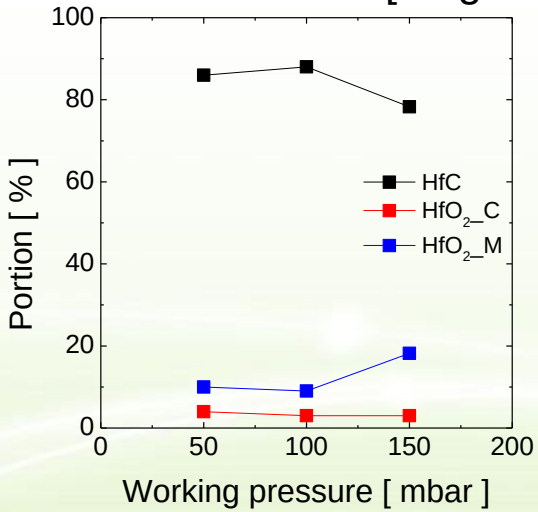
Results

Crystal Structure of HfC Coatings at Various Working Pressure





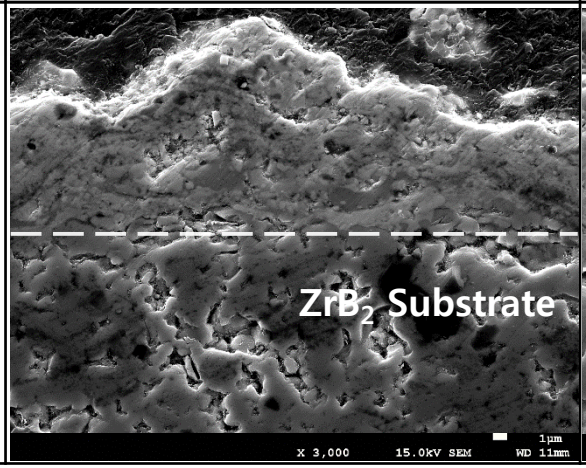
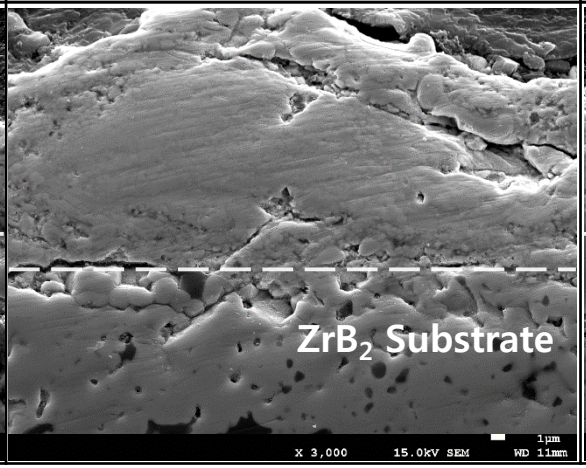
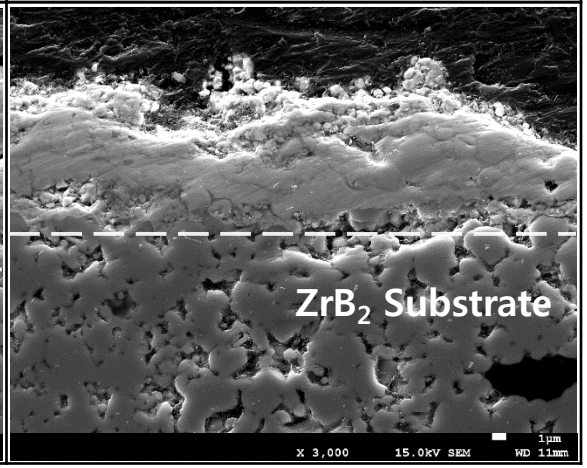
ZrB_2
HfO_2
HfC

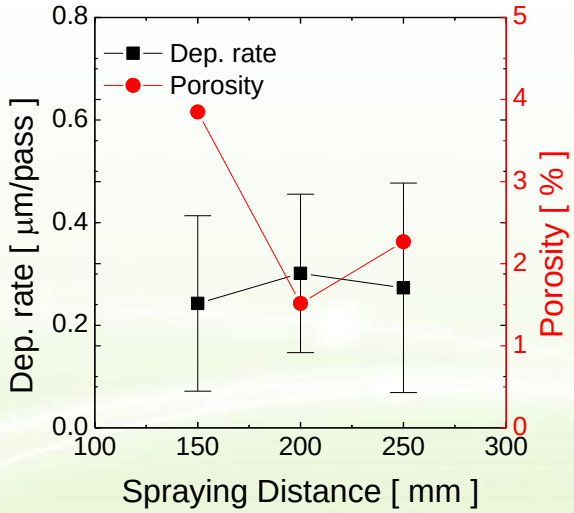


- HfC coatings including various phase of HfO_2 deposited at all working pressure.
- Little amount of HfC was coated on ZrB_2 at 150 mbar, so XRD spectrum showed peaks of ZrB_2.

Results

Microstructure of HfC Coatings at Various Spraying Distance

	150 mm	200 mm	250 mm
x3000			

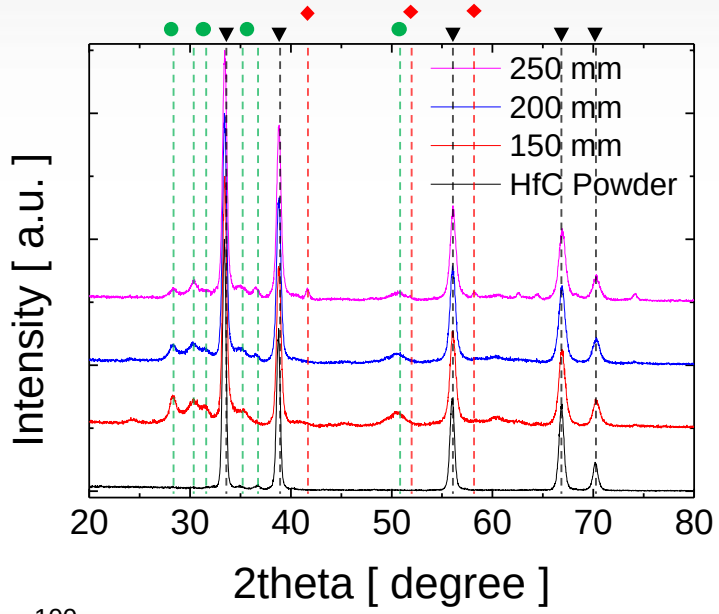


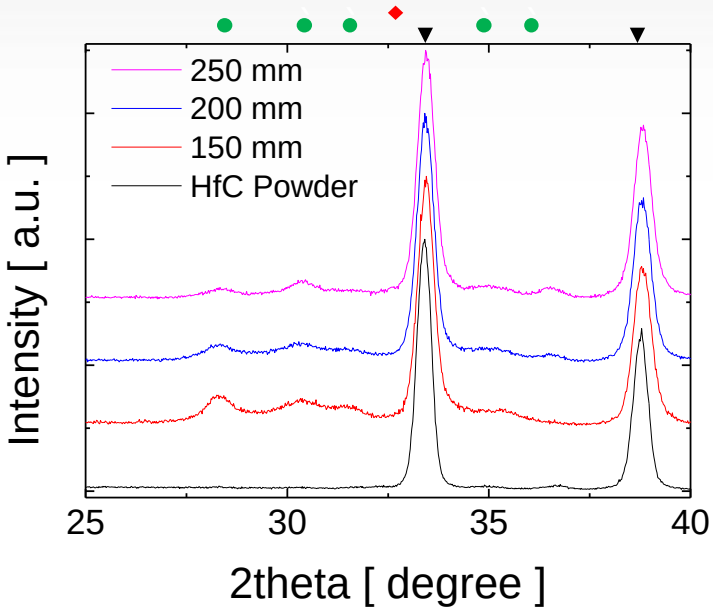
- Working pressure – 50 mbar

- Porous HfC coatings were deposited when spraying distance was not enough.
- No big difference of deposition rate between various spraying distance.

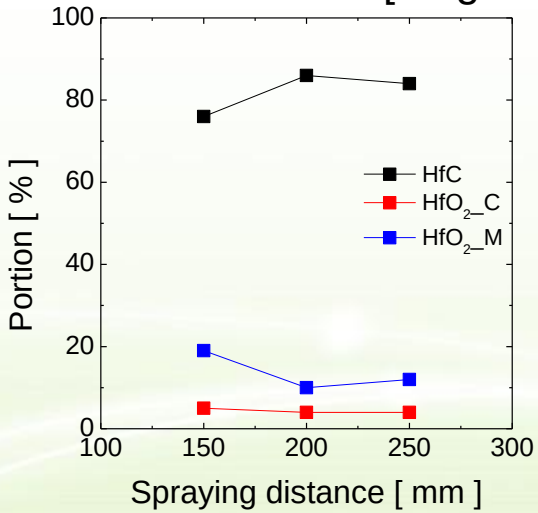
Results

Crystal Structure of HfC Coatings at Various Spraying Distance





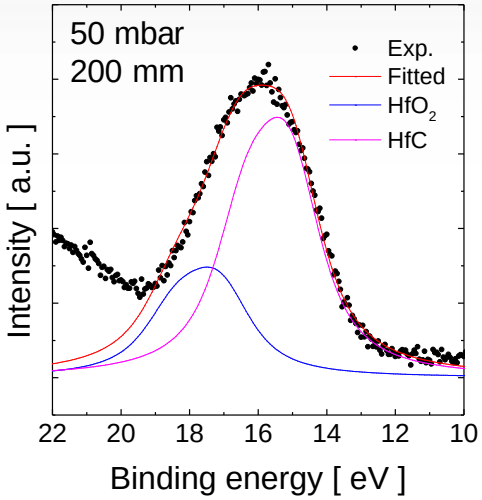
ZrB_2
HfO_2
HfC

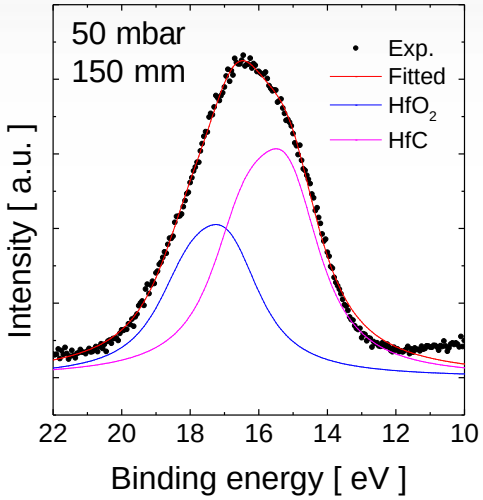


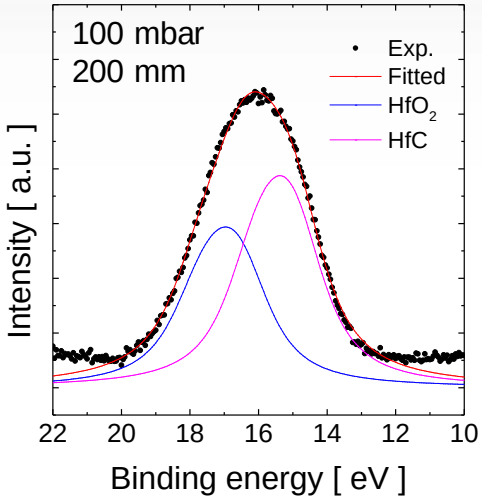
- As increasing spraying distance, the content of HfO_2 decreased.

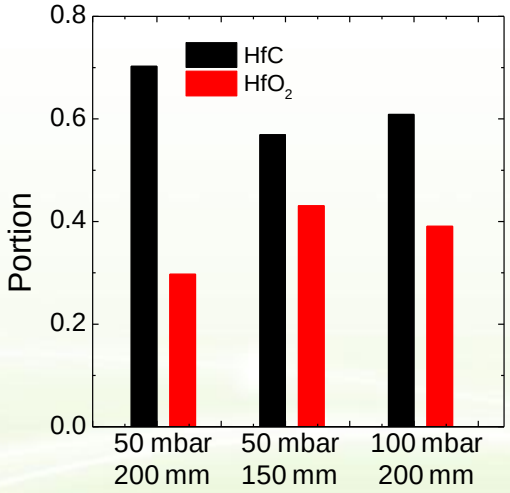
Results

XPS analysis of HfC Coatings









- The portion of oxide in HfC coating increased when spraying distance decreased.
- HfC coating deposited at low working pressure showed lower oxide content.

Summary

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TaC Coatings Deposited by VPS

- TaC coatings with TaO and Ta_2C were deposited by VPS
- Enough carrier gas flow was key parameter for reducing oxidation of TaC.
- Deposition TaC coating at low working pressure decreased carbon loss and made flatter splats.

HfC Coatings Deposited by VPS

- HfC coatings with various phases of HfO_2 were deposited by VPS.
- Coatings deposited at low working pressure showed lower oxide content.
- More oxide content in HfC coatings deposited when spraying distance is shorter than significant distance.

Comparison between Two Carbide Coatings

- TaC coatings showed that easier to oxidize than HfC coatings.
- Deposition rates of TaC coatings were higher than those of HfC coatings.
- TaC coatings showed more porous microstructure than HfC coatings.

Thank you
for
your attention!

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