Boron Carbide Coatings Deposited with HiPIMs

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Abstract

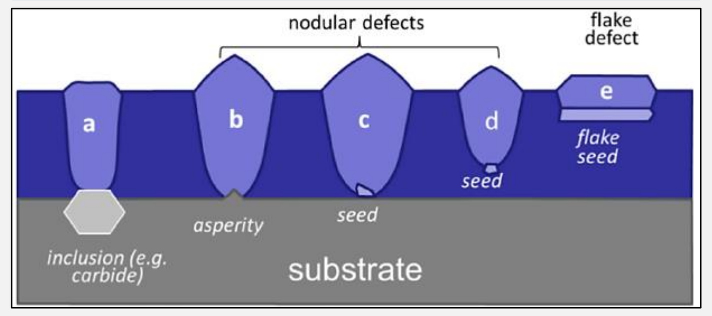
- Boron carbide possesses many key properties that make it particularly well suited as a next generation ablator platform for inertial confinement fusion research.
- Fine control of growth modes including nodular growth defects, and columnar growth at oblique angles remains a challenge.
- These growth modes and defects result in non-uniformity in the ablator capsule in the which will significantly reduce implosion performance (Rayleigh-Taylor Instability).
- Here, we investigate the deposition of amorphous boron carbide films using high power impulse magnetron sputtering using a full faced erosion magnetron source.

Background

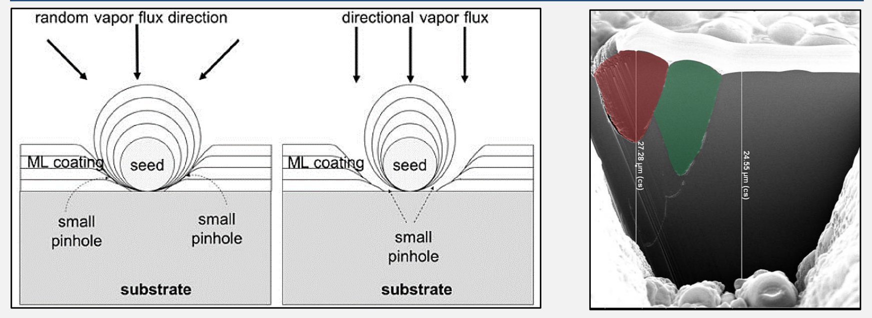
Nodular Growth Defects

- Nodular growth defects are irregularities that manifest from the film growth process.
- In PVD these typically come in the form of conical or parabolic nodular defects.
  - Particulate contamination on substrate
  - Discharge "arc" from target
  - Process stability
  - "Dusty Plasma"

Types of Growth Defects

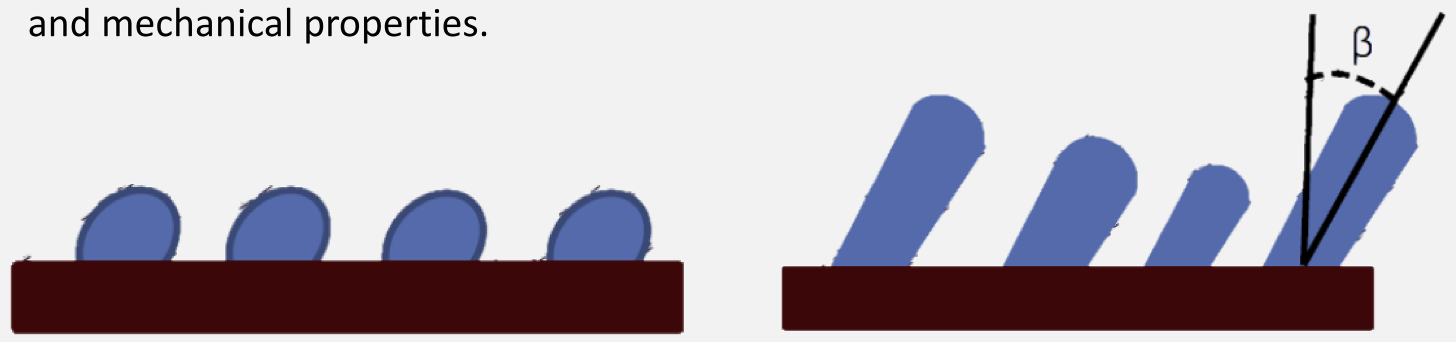


Nodular Growth Mechanics



Columnar Growth Modes

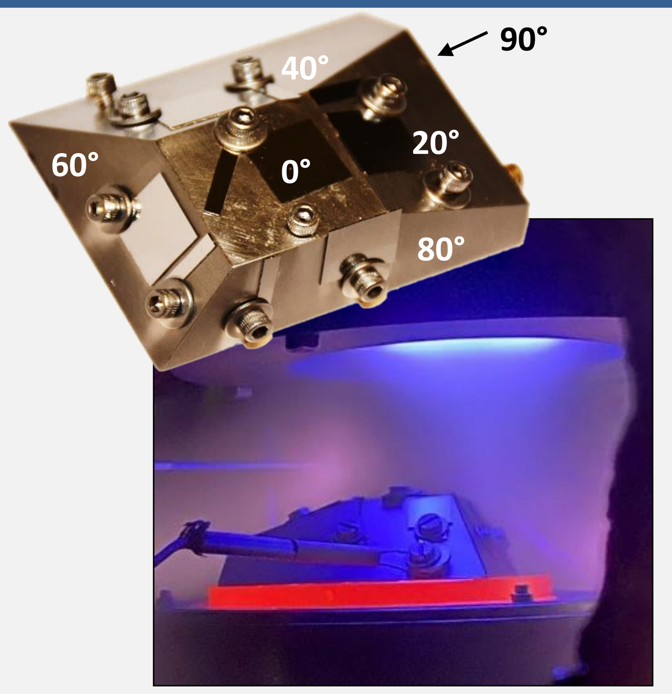
- Columnar growth is driven by shadowing effects due to the limited particle flux behind formed nuclei. Enhanced due to low adatom mobility.
- Columnar growth can increase porosity thereby leading to a reduction of film density and mechanical properties.



Summary box / Takeaway option if needed

Experimental Parameters

- **Magnetron Type:** Full-faced erosion, MAK-gun
- **Si Substrate Tilt Angles** (°): 0, 20, 40, 60, 80, 90
- **Working Pressure** (mTorr): 20, 36
- **Working Gases** (4N): Ar, 80 Ar/ 20 Ne
- **Target to substrate distance** ("): 2
- **Substrate Temperature** (°C): 450
- **Power Types**: 13.56 MHz RF, HiPIMS
- **Power**: 300 W RF, 500 W (avg.) HiPIMS
- **Substrate Bias** (V): 0 , -50 (HiPIMS only)



Reduction of Nodular Growth Defects

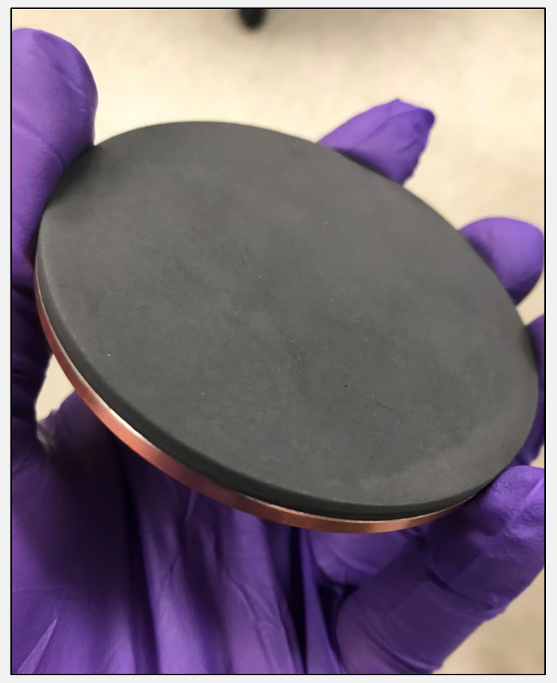
RF Deposition Parameters

Run #	Magnetron Rotation Speed (RPM	Target Thickness (mm)	Sub. Temp (°C)	TSD (")	Pressure (mTorr)
1	100	5.9	450	2	27
2	100	5.7	450	2	36
3	200	4.7	450	2	36

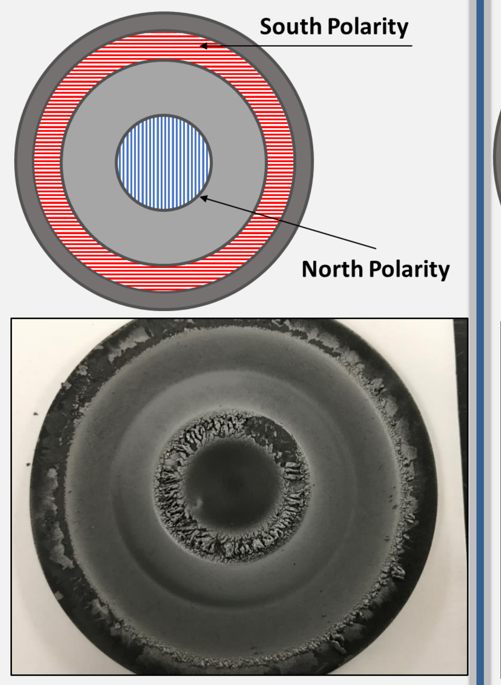
Residual stress was studied as a function of FFE Rotation speed and FFE target thickness.

Effect of Magnetron Design on Target Condition

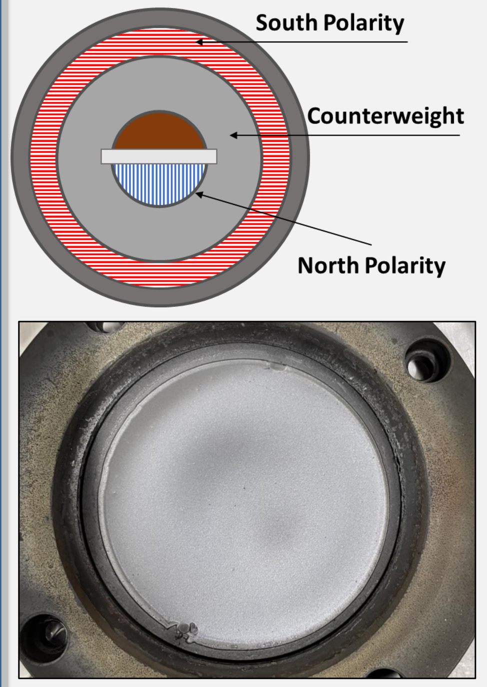
Pre-Deposition B_4C Target Condition



MAK-Gun Target Condition



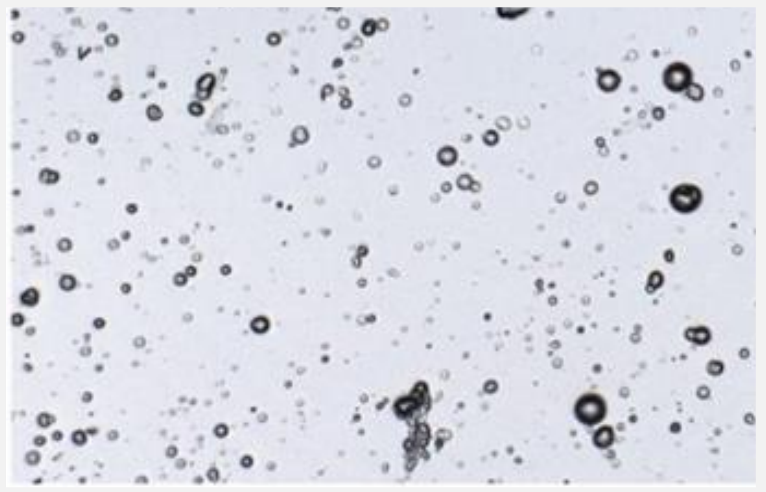
FFE Target Condition



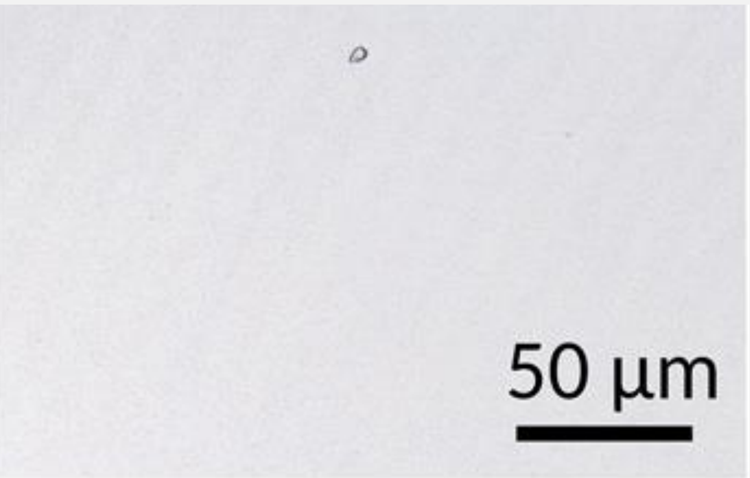
Redeposition of "dust" from plasma onto target virtually eliminated with FFE.

Nodule Defect Density

MAK-Gun

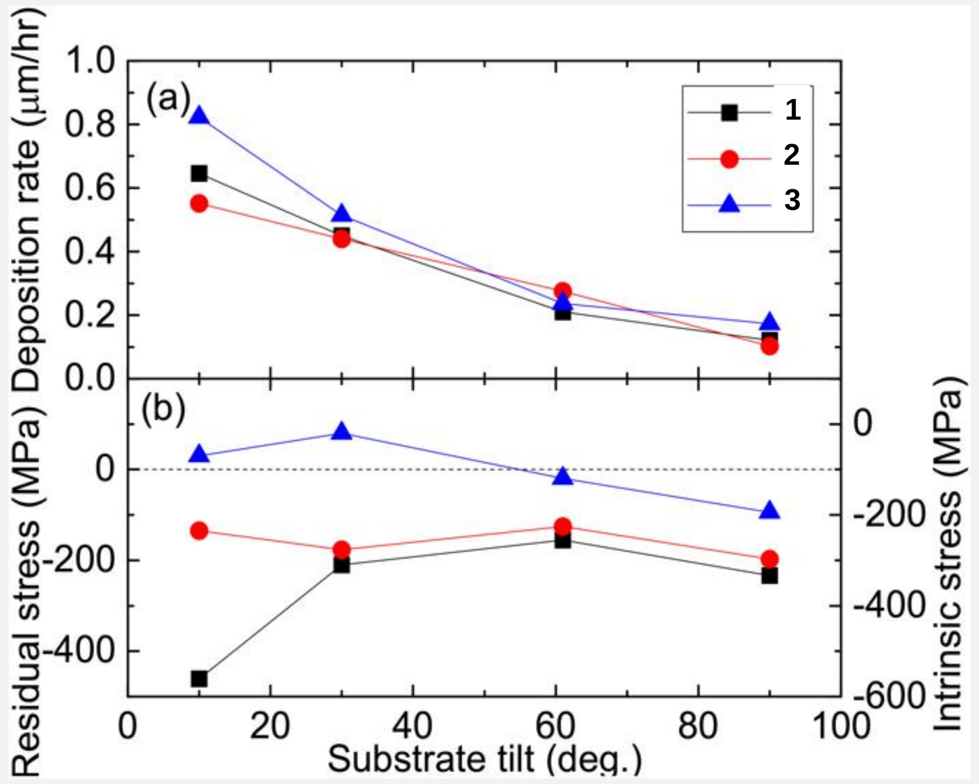


Full Face Erosion Magnetron



Confocal micrographs show the contrast in nodular defect density between MAK and FFE sources.

Residual Stress and Deposition Rate

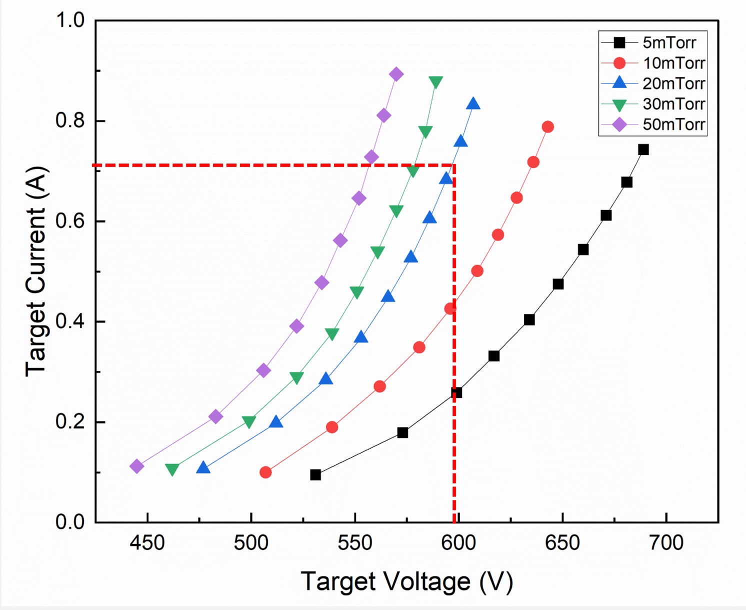


Additional Considerations

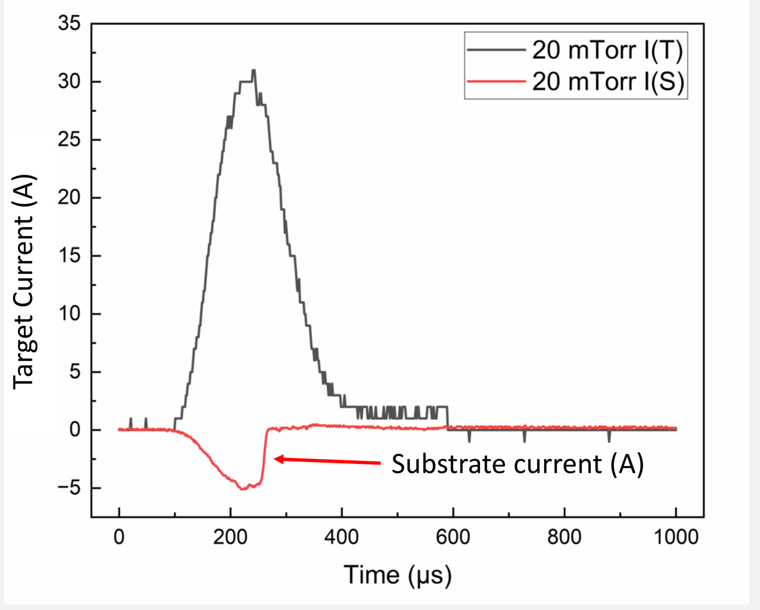
- Use CTE matching magnetron components and materials.
- Heating of adjacent surfaces to enhance B4C adhesion.
- Operating and lower base pressures to reduce the occurrence of arcing and thereby droplets.
- Magnetron to substrate geometry and orientation.

Columnar Growth Modification with HiPIMS

DC & HiPIMS I-V Characteristics

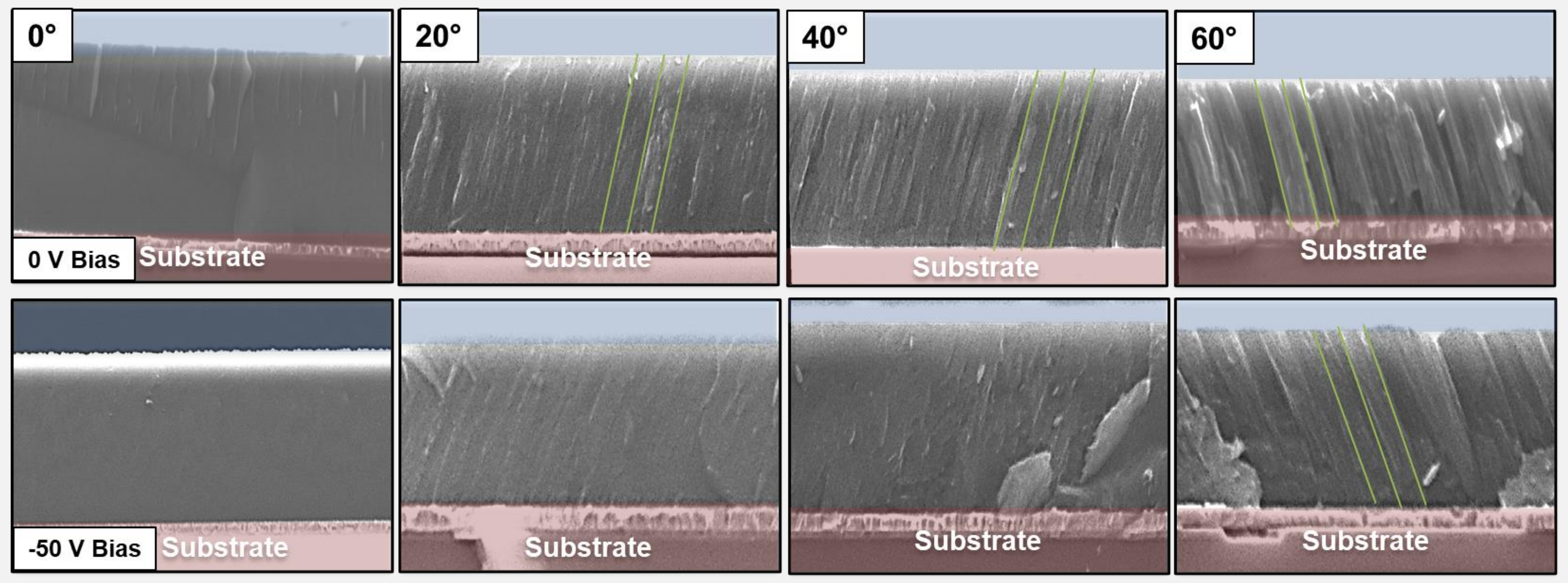


Higher working pressure results in higher target current for a given voltage



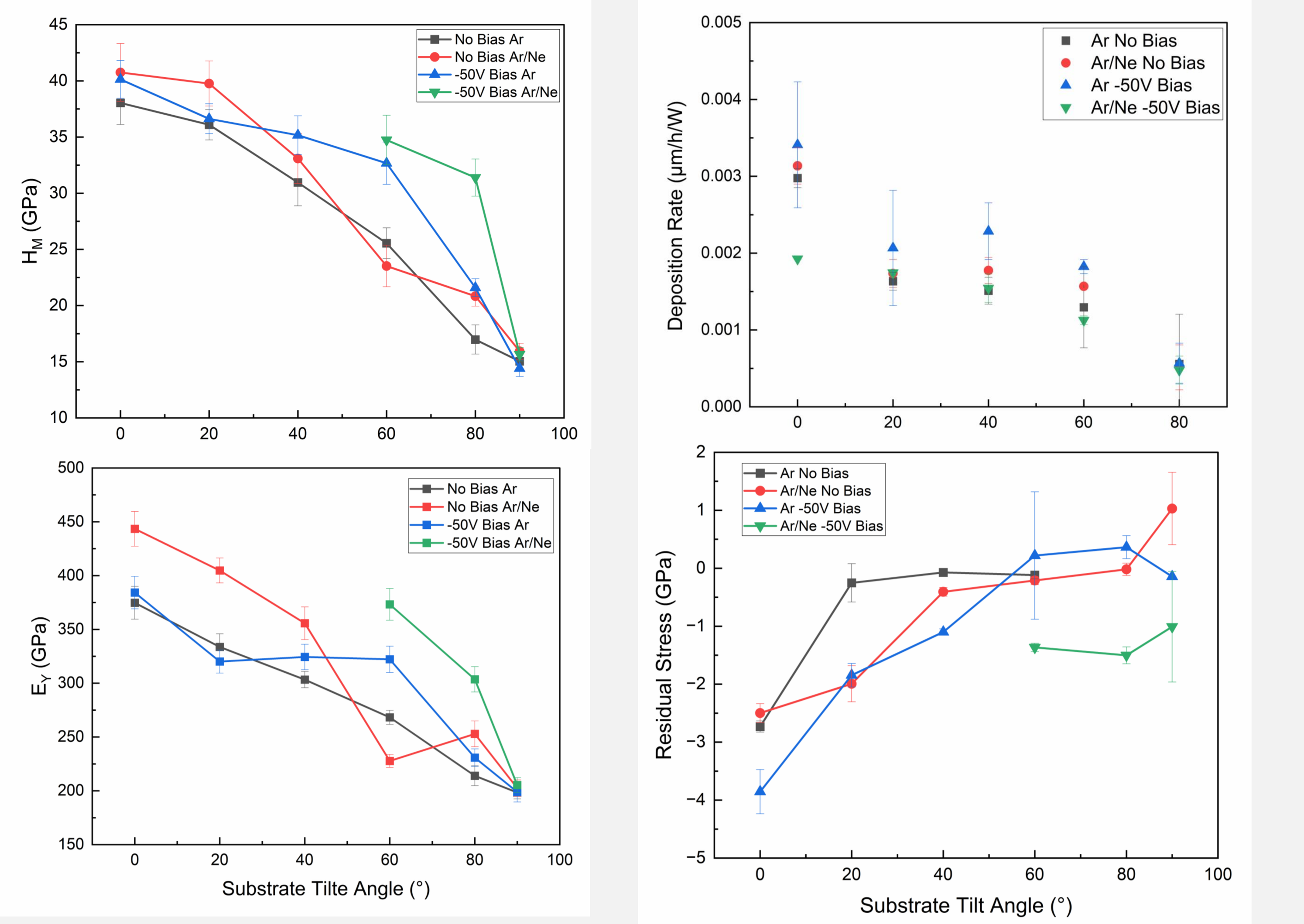
DC-IV Characteristics leveraged to achieve high peak target and substrate current with HiPIMS

Cross-sectional Microstructure



Redeposition of dust from plasma onto target significantly reduced with FFE.

HiPIMS B_4C Coating Properties



Conclusions and Future Work

- Reduction of nodular growth defects and suppression of columnar growth (≤ 40°) can be accomplished using HiPIMS in tandem with FFE magnetron source.
- B_4C deposited using HiPIMS results in extremely hard coatings with high compressive residual stress.
- Further research is required to reduce residual stress of coatings.

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