nano4ENERGY
institute iMdea materials
www.materials.imdea.org

Optimization of AlTiBN coatings deposited by HiPIMS

A. Mendez[1,2,3]; J. Santiago[1]; I. Fernández-Martínez[1]; A. Wennberg[1]; M.A. Monclús[2]; and J.M. Molina-Aldareguía[2]

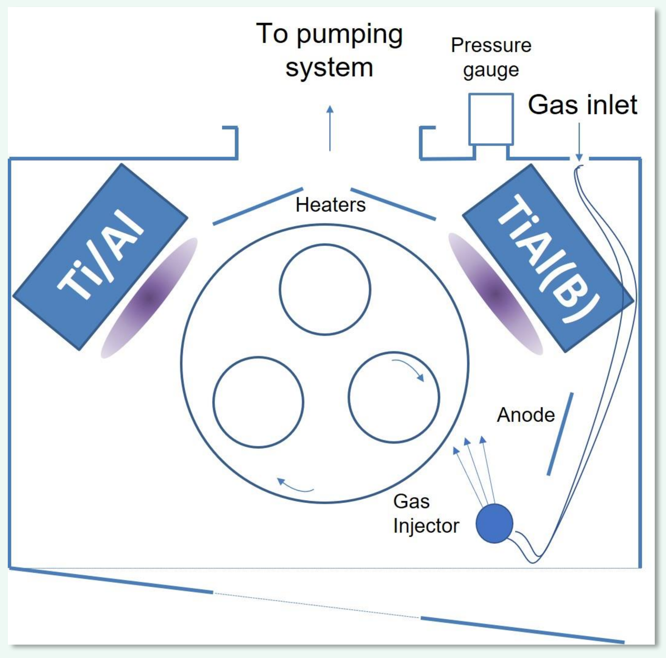
[1] E.T.S. de Ingenieros de Caminos, Universidad Politécnica de Madrid, Campus Ciudad Universitaria, c/Prof. Aranguren, 3, 28040 Madrid, Spain;
[2] Nano4Energy SL, c/José Gutiérrez Abascal, 2, 28006 Madrid, Spain;
[3] IMDEA Materials Institute, c/Eric Kandel 2, 28906 Getafe, Spain;

MOTIVATION

- Hard nitride (Ti, Al)N-based coatings deposited by magnetron sputtering (MS) suffer from limited thermal stability and fracture toughness.
- HiPIMS method offer higher energetic deposition conditions.
- AlTiBN and AlTiN coatings were deposited by HiPIMS to study the effect of Al content and B doping. AlTiBN also deposited by DCMS for comparison with HiPIMS.
- Al_xTi_{1-x}(B)N *deposited with x ratios* between 0.50 and 0.80.

Aim: Produce harder and thougher AlTiBN coatings suitable for high temperature applications.

COATINGS DEPOSITION SETUP AND COMPOSITIONS



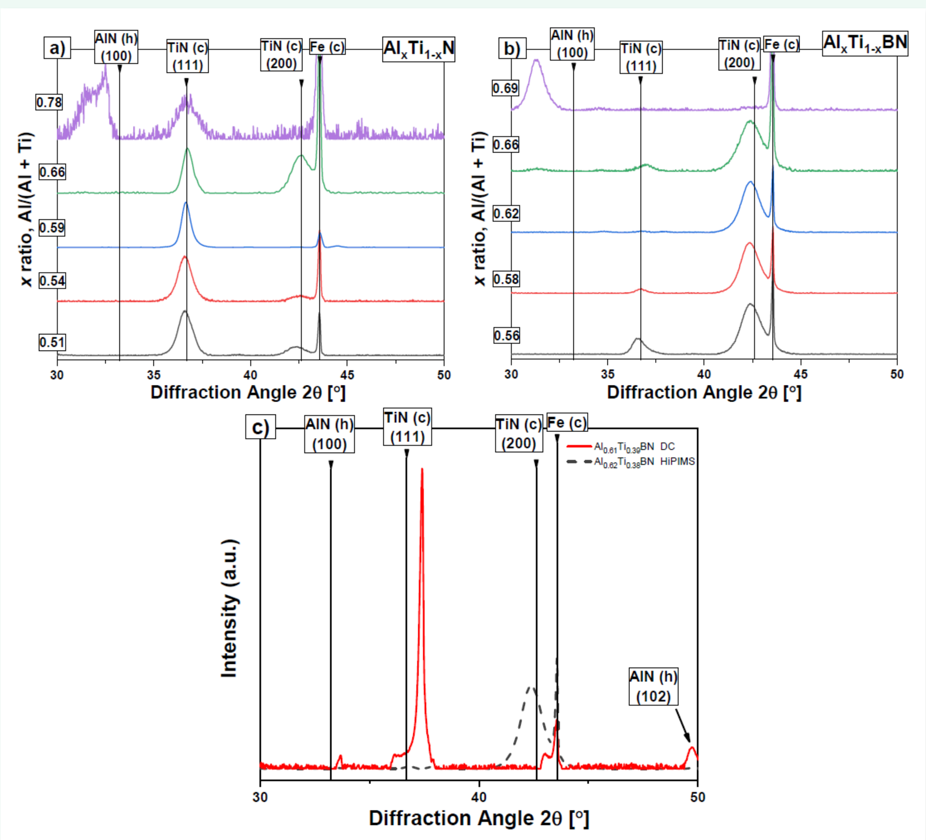
Industrial-scale deposition setup.

Coating	Targets	Power	Composition (at.%) Al	Ti	B	N	x	Thickness (µm)	Deposition Rate (µm/h)
AlTiN-1	$Al_{50}Ti_{50}$ + Ti	3kW and 0.5kW	24.40	23.80	—	51.73	0.51	2.45	0.98
AlTiN-2	$Al_{50}Ti_{50}$	3kW	25.79	21.85	—	52.27	0.54	1.99	0.80
AlTiN-3	$Al_{50}Ti_{50}$ + Al	3kW and 0.25kW	26.79	18.67	—	54.55	0.59	1.59	0.64
AlTiN-4	$Al_{50}Ti_{50}$ + Al	3kW and 0.5kW	29.36	14.98	—	55.39	0.66	1.69	0.68
AlTiN-5	$Al_{50}Ti_{50}$ + Al	3kW and 2.0kW	34.61	9.80	—	55.25	0.78	2.75	1.1
AlTiBN-1	$Al_{55}Ti_{35}B_{10}$ + Ti	3kW and 2.0kW	25.35	20.12	0.85	53.43	0.56	2.66	1.33
AlTiBN-2	$Al_{55}Ti_{35}B_{10}$ + Ti	3kW and 1.5kW	26.69	19.35	0.91	52.35	0.58	2.01	1.01
AlTiBN-3	$Al_{55}Ti_{35}B_{10}$ + Ti	3kW and 1.0kW	28.44	17.50	0.97	52.58	0.62	1.80	0.90
AlTiBN-4	$Al_{55}Ti_{35}B_{10}$ + Ti	3kW and 0.5kW	30.36	15.68	1.10	52.55	0.66	1.67	0.84
AlTiBN-5	$Al_{55}Ti_{35}B_{10}$	3kW	31.31	14.18	1.19	53.31	0.69	1.59	0.80
AlTiBN DC	$Al_{55}Ti_{35}B_{10}$ + Ti	3kW and 1.0kW	27.87	17.67	3.68	50.01	0.61	3.51	1.76

Deposition procedure and composition results extracted from GDOES analysis.

PROPERTIES

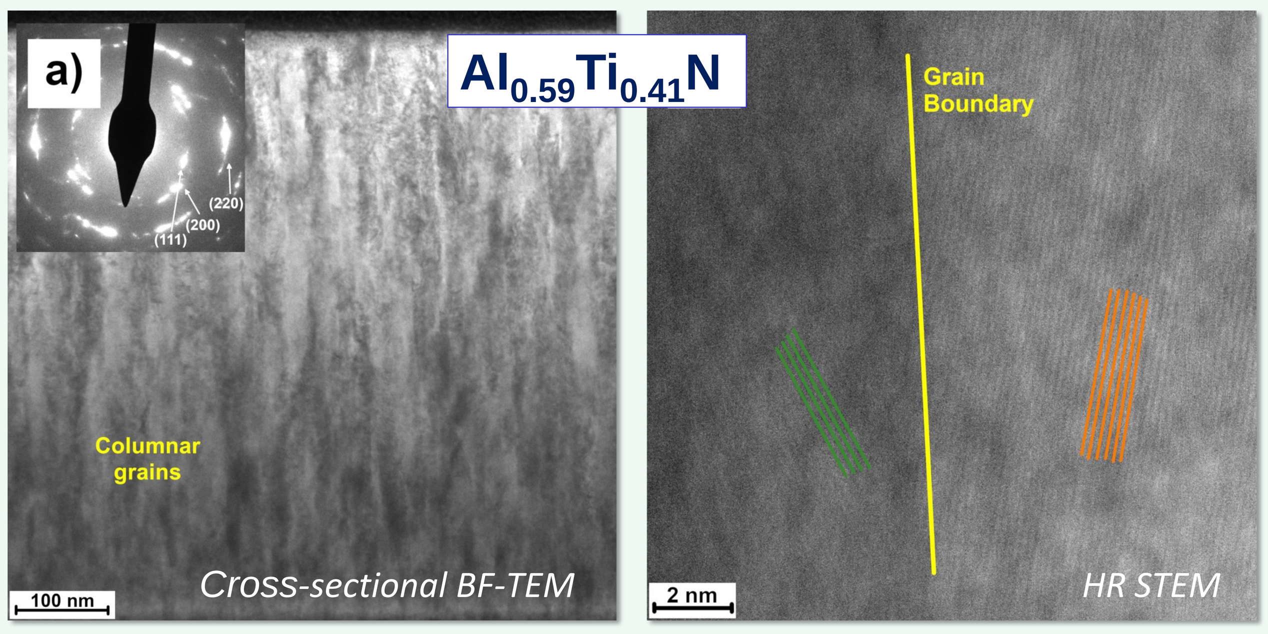
XRD



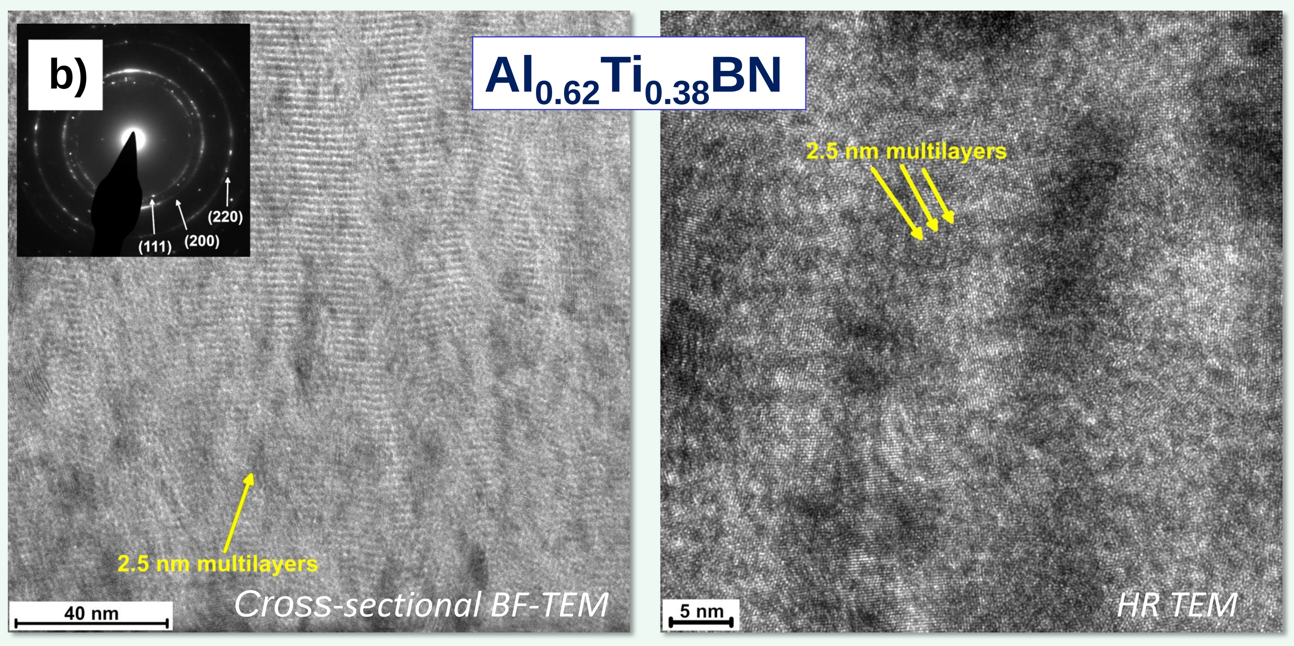
a) $Al_xTi_{1-x}N$ HiPIMS, b) $Al_xTi_{1-x}BN$ HiPIMS and c) $Al_xTi_{1-x}BN$ DCMS (c) XRD spectra.

- Coatings up to x = 0.6 present a predominant fcc-cubic structure.
- B-doping, in combination with HiPIMS energetic bombardment, promotes (200) orientation over (111).
- At high x ratios and low-energy bombardment (DCMS), the detrimental hex-AlN phase appears.

TEM



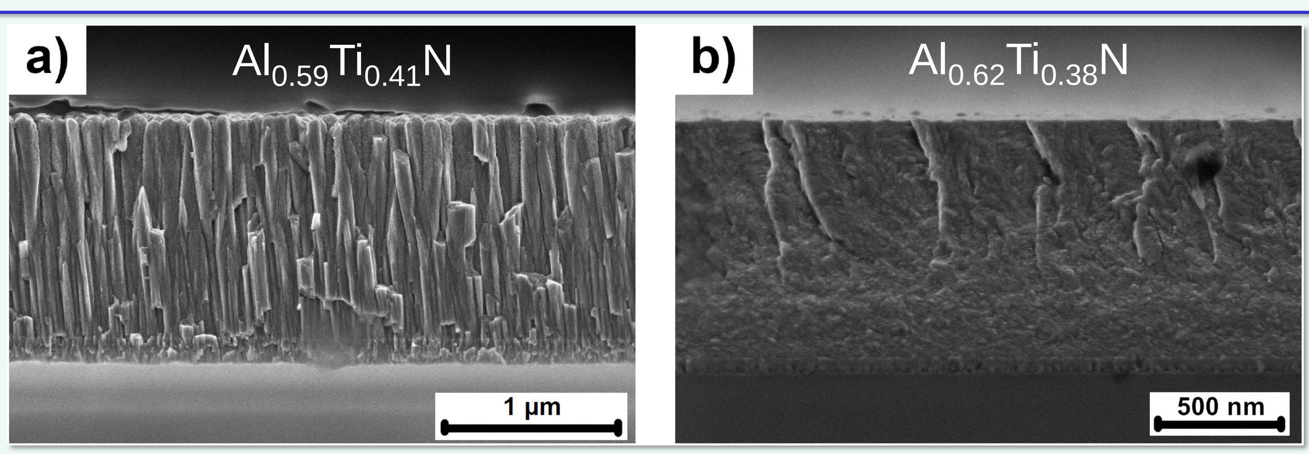
- Dense columnar structure of ~20 nm wide grains oriented in the growth direction.
- Lattice planes extend continuously within the columnar grains and are interrupted by the grain boundary showing high degree of crystallinity.



- Multilayer pattern resulted from substrate rotation during co-sputtering and the presence of B.
- B-addition triggered the formation of a more nanocrystalline structure.
- ≈14 at. % B (from EELS).

- HiPIMS and B doping results in a dense **nanocomposite microstructure** composed of nanocrystalline Ti(Al)N domains (≈ 2 nm) and amorphous regions [Ti(Al)B_2 and BN].

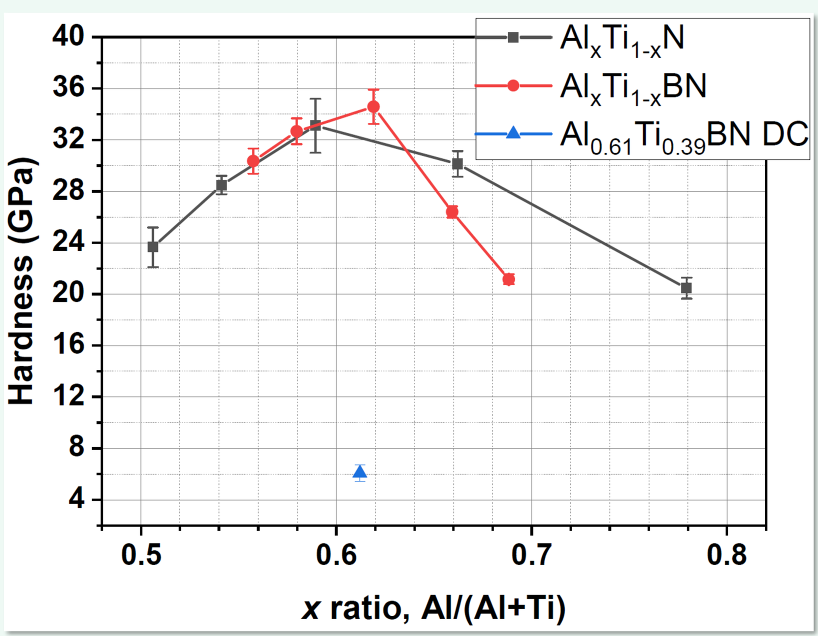
SEM



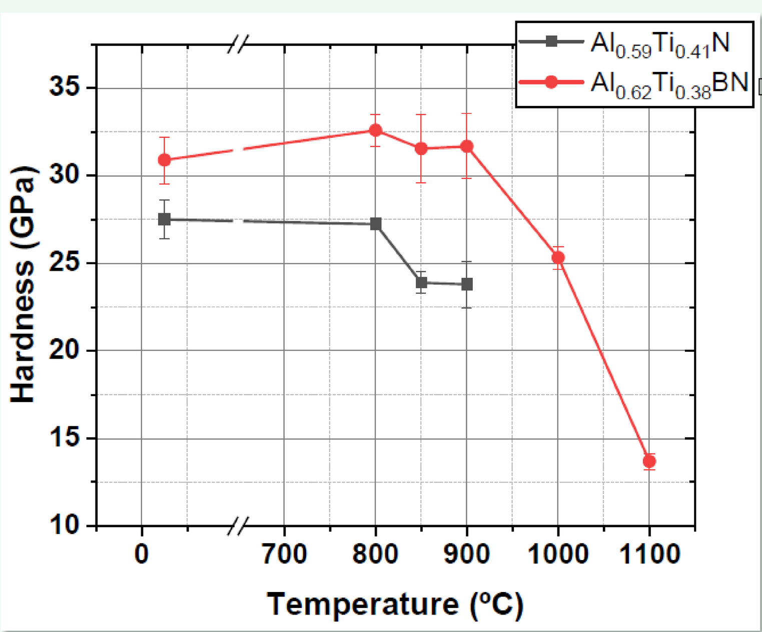
$Al_{0.59}Ti_{0.41}N$ shows a columnar structure.

$Al_{0.62}Ti_{0.38}BN$ shows a fine-grained structure.

Nanoindentation



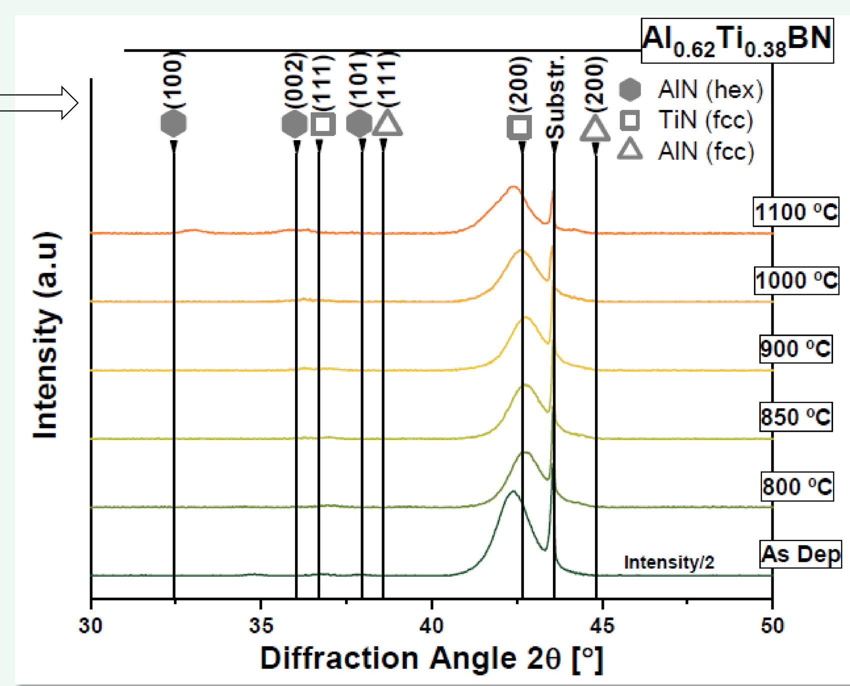
As-deposited hardness tests.



Hardness tests after vacuum annealing.

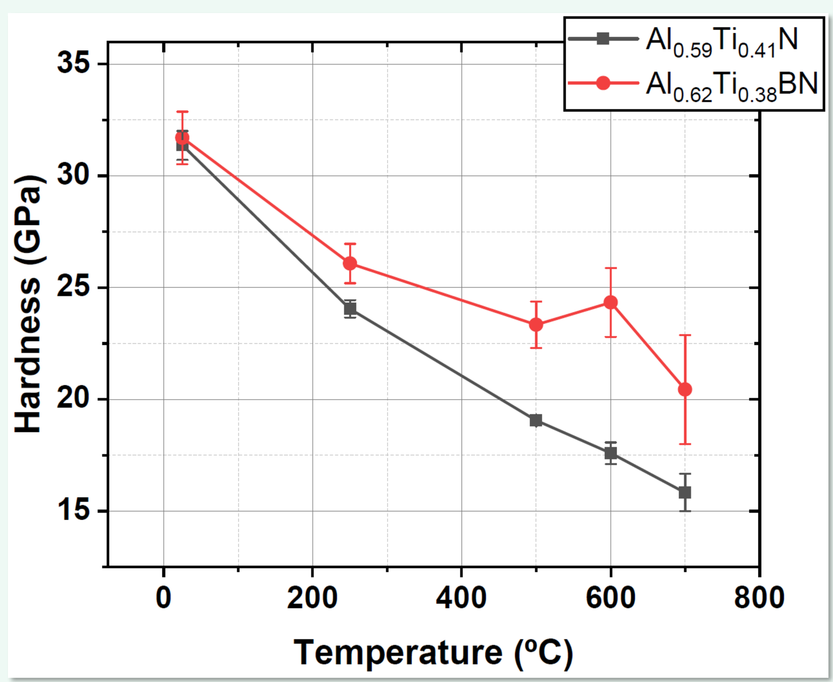
- Al_xTi_{1-x}(B)N with x ≈ 0.6 offer the highest hardness.
- Higher H/E and H^3/E^2 ratios for $Al_xTi_{1-x}BN$ suggest ↑ fracture toughness.
- $Al_{0.62}B_{0.38}BN$ offers improved thermal stability (up to 1100 ºC).

XRD (After vacuum annealing)



- Formation onset of detrimental h-AlN delayed from 850 ºC for $Al_{0.59}Ti_{0.41}N$ to 1100 ºC for $Al_{0.62}B_{0.38}BN$.

Hot hardness



- Superior hot hardness for $Al_{0.62}B_{0.38}BN$ up to 750 ºC ⇒ better performance for high temperature applications.

FURTHER INFORMATION

- A. Mendez et al. Surface & Coatings Technology 422 (2021) 127513 https://doi.org/10.1016/j.surfcoat.2021.127513

ACKNOWLEDGEMENTS

- This investigation was supported by the Comunidad de Madrid under the Industrial Doctorate program (IND2018/IND-9668).