A Cold Spray Horizon: Innovative Multifunctional Composite Coatings for Superior Performance

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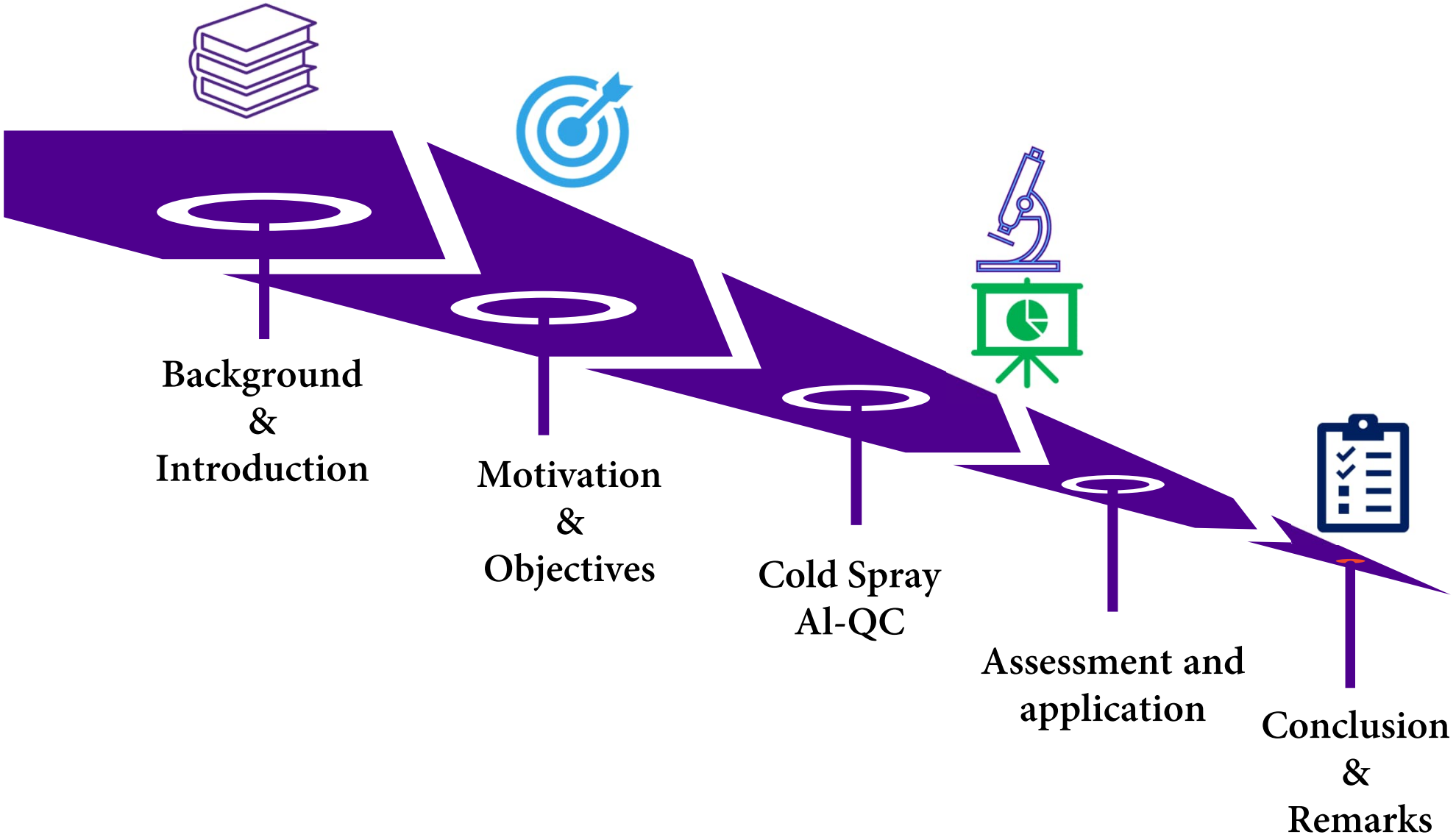
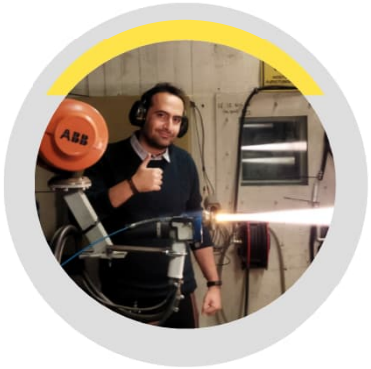
12th December 2023

OUTLINE


Background & Introduction
Motivation & Objectives
Cold Spray Al-QC
Assessment and application
Conclusion & Remarks

TEAM



REZA JAFARI

Doctoral Researcher in Materials Science and Environmental Engineering

Research interest:

Cold and Thermal Spray Coatings, Material characterization, Material testing in demanding environment (Non-ambient temperature, Corrosive media)

HELI KOIVULUOTO

Assoc. Professor (Tenure Track) in Coating technologies and icing research

Tampere University, Materials Science and Environmental Engineering

Fields of Expertise:

Surface Engineering: Cold Spraying and Thermal Spraying, Coating Properties and Performances Evaluation, Icing and Freezing research, Ice repellant surfaces

MINNAMARI VIPPOLA

Professor in Materials Characterization

Vice Dean for Research, Faculty of Engineering and Natural Sciences

Head of Tampere Microscopy Center

Fields of Expertise:

Microstructural Characterization And NDT (Non-destructive Testing) of Various Materials Together with Activities in Material Processing, Performance and Failure Analysis

MARI HONKANEN

Senior Scientist

Faculty of Engineering and Natural Sciences

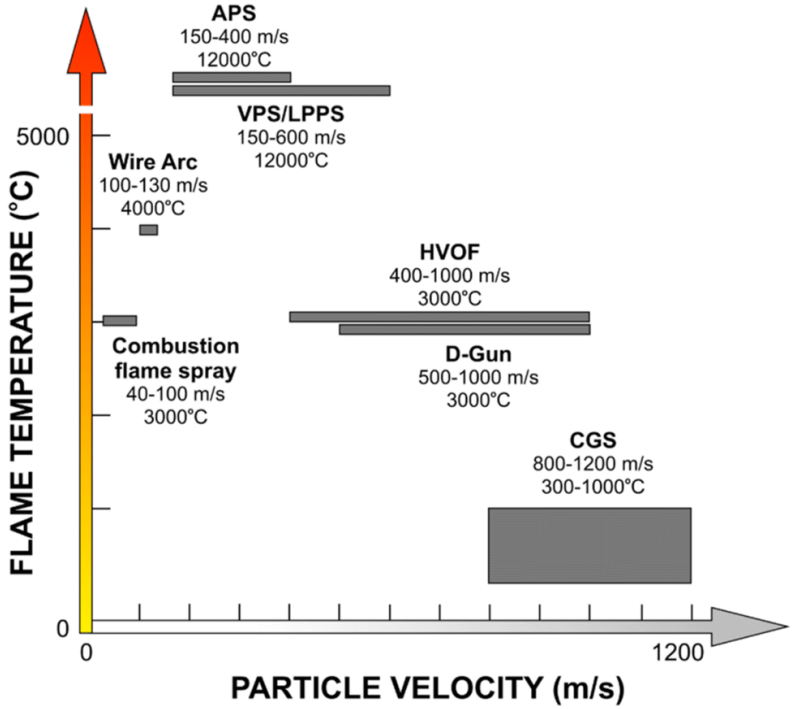
Coordinator and Facilitator at Tampere Microscopy Center

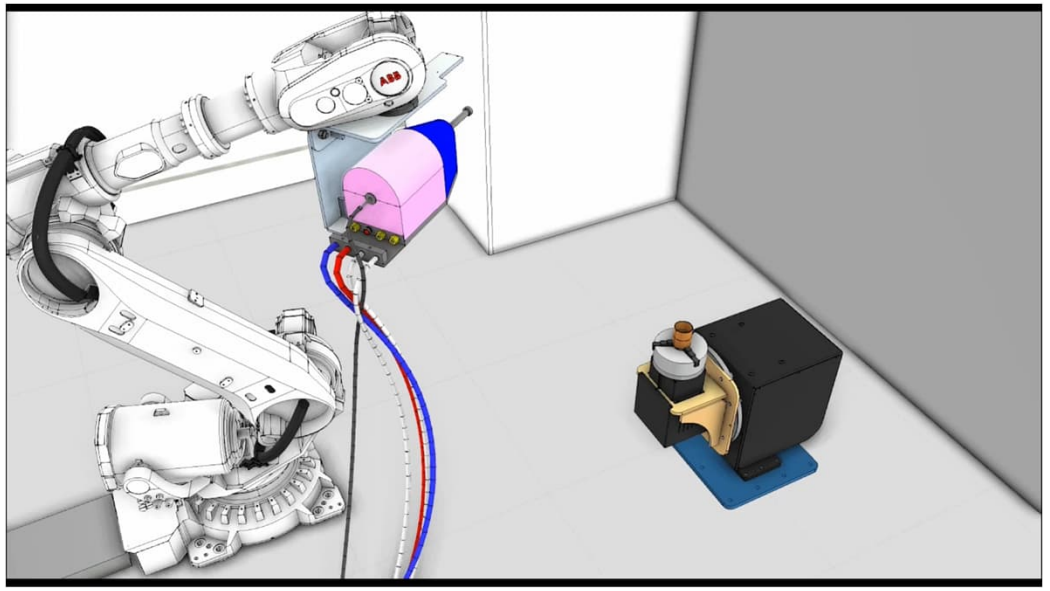
Fields of Expertise:

Characterization of catalysts, other nanomaterials and structures, magnetic materials, steels, composites, ceramics, coatings, bio-based materials etc.

INTRODUCTION

Cold spraying





Video sources: Delfoi in collaboration with TAU (Heli Koivuluoto), Impact Innovations GMBH

Feedstock materials

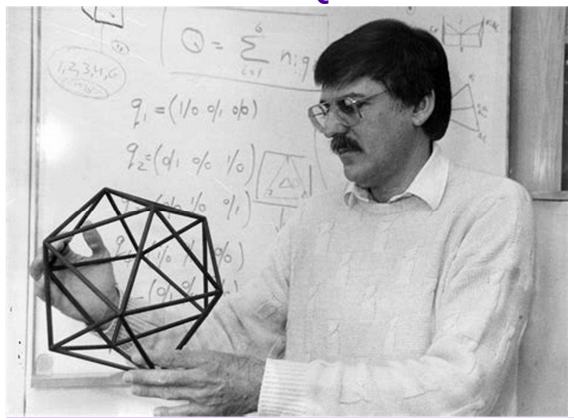
- Pure metals and engineering alloys
- Metallic
- Ceramics
- High entropy alloys
- Composites

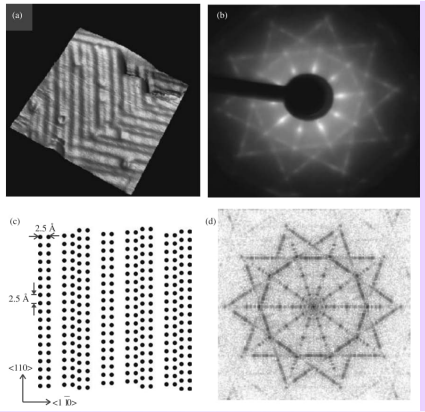
Substrates

- Metals
- Ceramics
- Polymers

Tejero-Martin, D., Rezvani Rad, M., McDonald, A. et al. Beyond Traditional Coatings: A Review on Thermal-Sprayed Functional and Smart Coatings. J Therm Spray Tech 28, 598–644 (2019)

HISTORY OF QUASICRYSTALS





1982, Dan Shechtman

a pattern of dots that was impossible for a regular crystal.

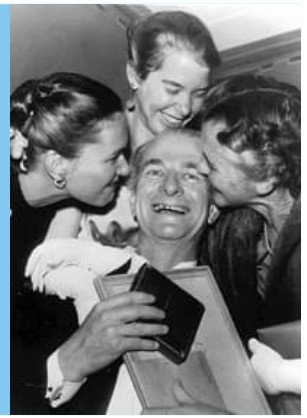
"*There can be no such creature.*"

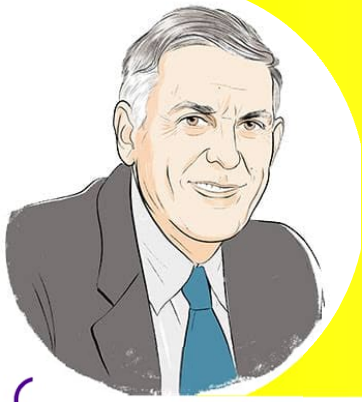
Quasicrystal, meaning "almost crystal"

Linus Pauling a double Nobel laureate in chemistry and peace:

"Danny Shechtman is talking nonsense,

there are no quasicrystals, just quasi-scientists."





In 2011, Dan Shechtman was awarded the **Nobel Prize in Chemistry**, for the discovery of quasicrystals.

- Solid that differs from the other two known states: crystal and amorphous
- Exhibiting rotational symmetries (Unlike crystals) like 5 and 10 folds
- Intermetallic compounds (mostly Al-based) possessing long-range order, despite their lack of periodicity

Properties

- Low friction materials
- Low surface energy (down to 30 mJ/m^2)
- Relatively high hardness and high melting point
- Low thermal conductivity
- Infrared absorption

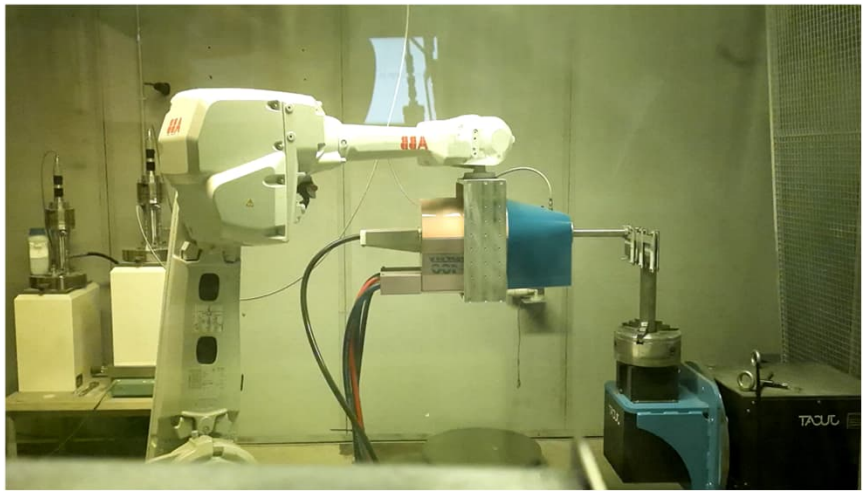
Applications?

- Wear resistant coating
- Nonsticking surfaces
- Catalyst surfaces
- Hydro-/ice-phobic coatings
- TBC for moderate temperature

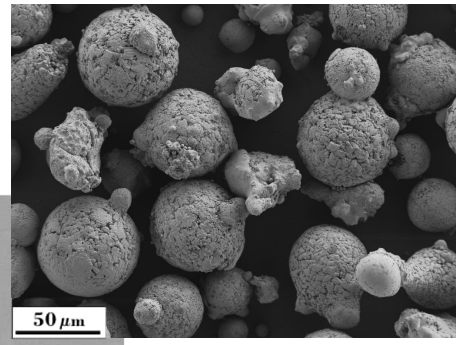
(H.R. Sharma, et.al, Adv. Phys. 56 (2017))

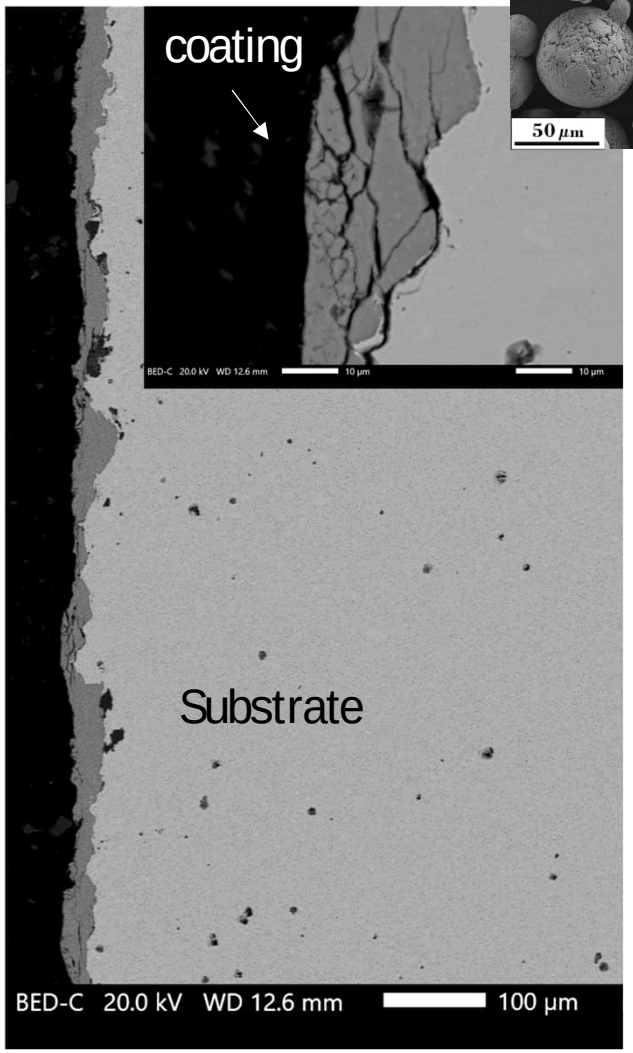
COLD SPRAY OF QC PARTICLES

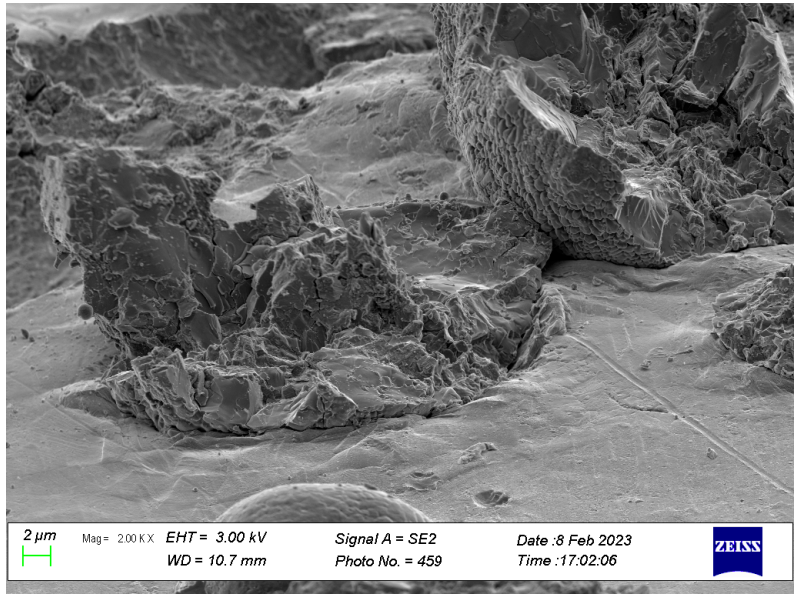
High Pressure Cold Spraying



Low Pressure Cold Spraying





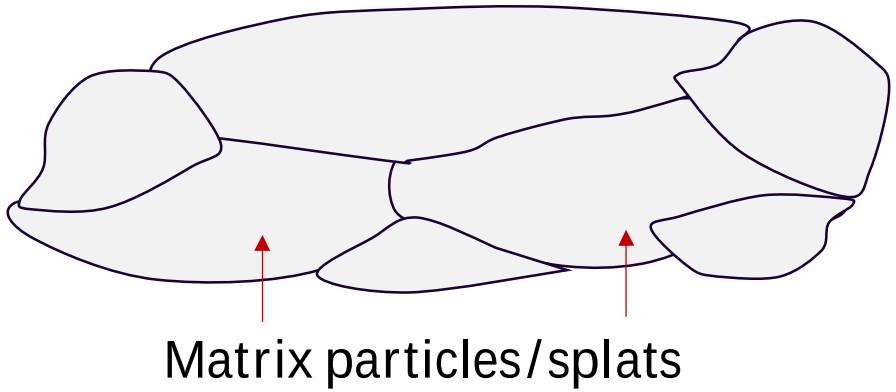


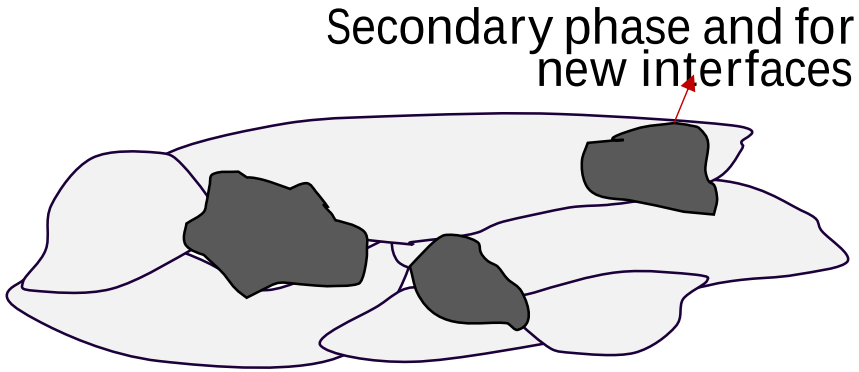
MOTIVATION FOR DEVELOPING COLD SPRAYED AL-QC COMPOSITE COATINGS

Possibility of composite formation by cold spraying?

What kind of functionality and properties can be achieved by composite formation?

What are the underneath phenomena that causes alteration in properties?

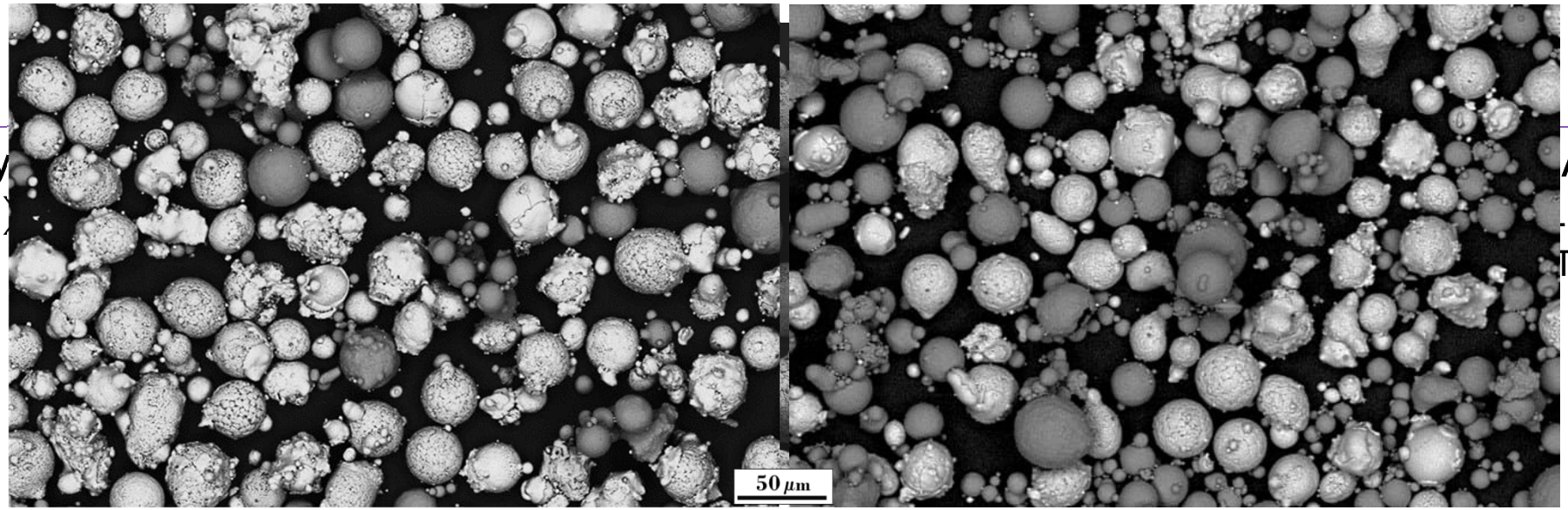




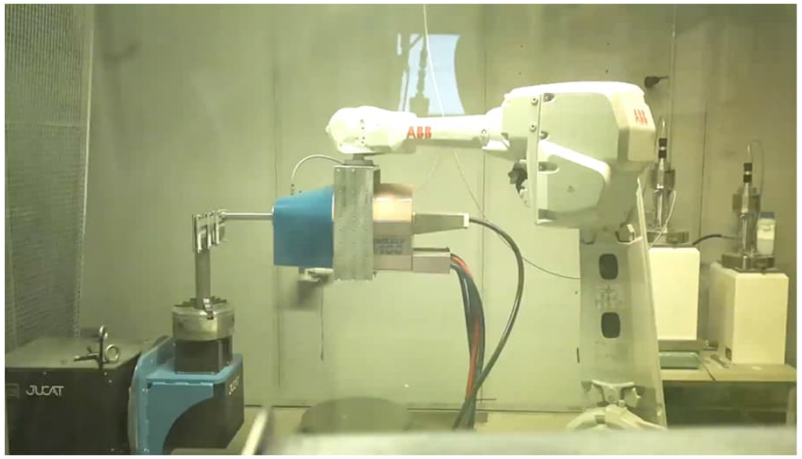
Does addition of the secondary phase improve or compromise the microstructural integrity of the coatings?

HIGH PRESSURE COLD SPRAYING: MATERIALS AND PROCESS

AlCrFeCu Quasicry
(20–53 µm)
(Saint-Gobain Coating



AA6061
5–50 µm)
Technik GmbH)



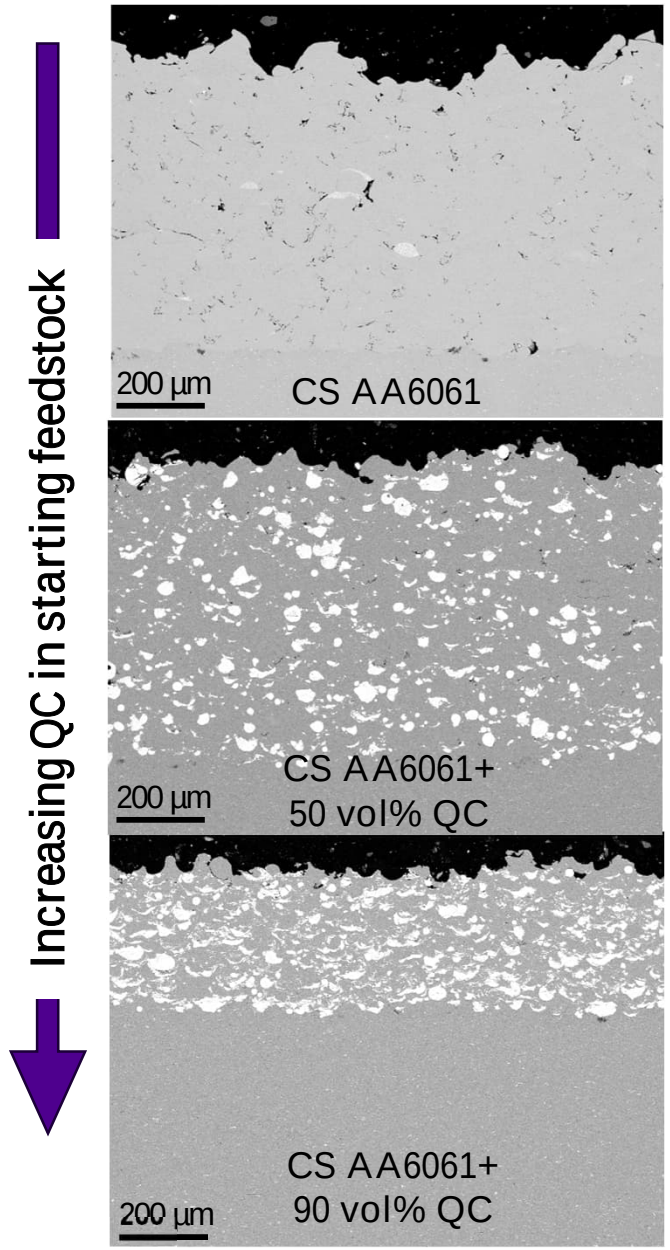
PCS-100 (Plasma Giken Co., Ltd.)

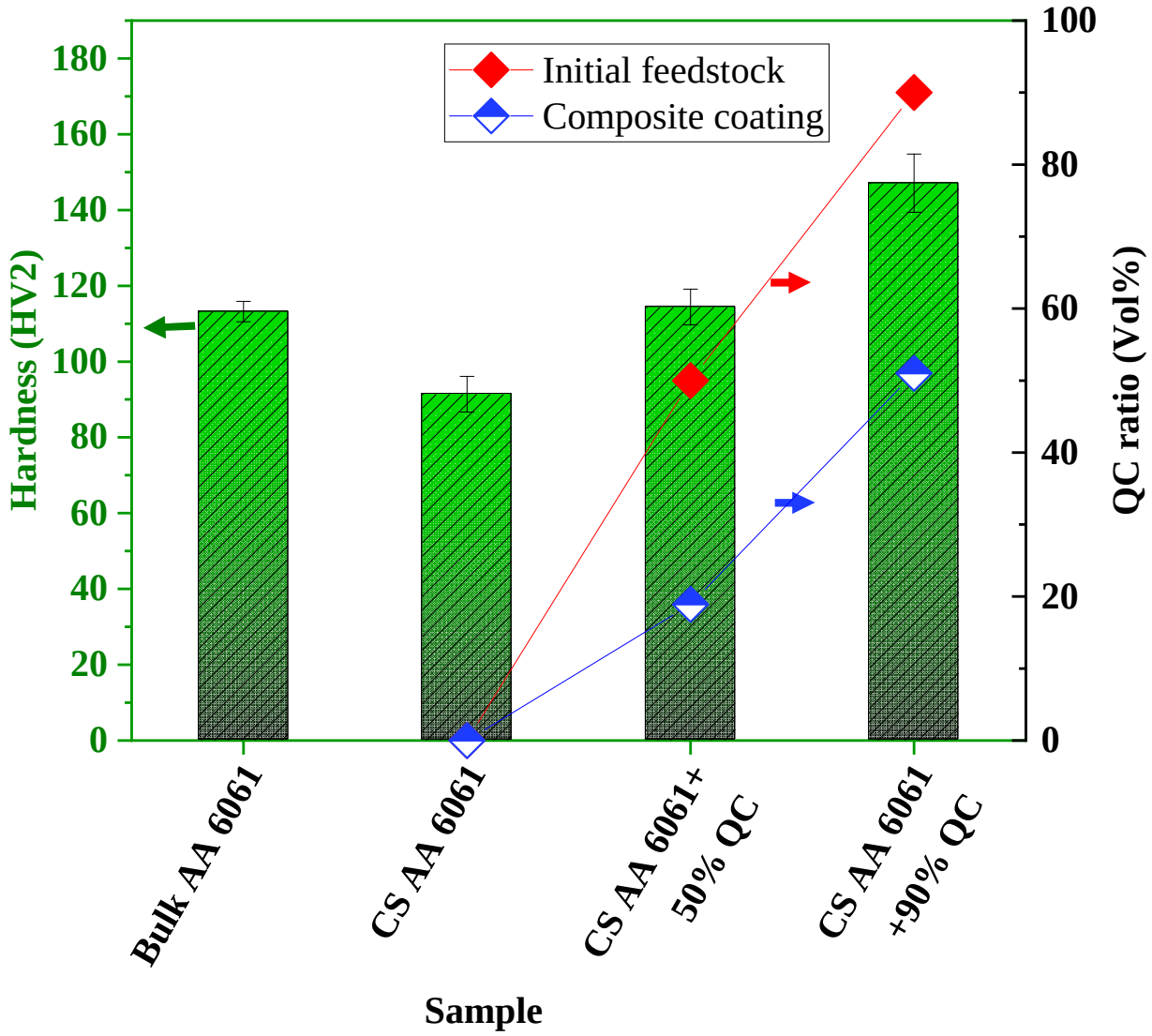
Parameters	$P(N_2)$	$T(N_2)$	Layer	Feed rate	Trav. speed	SoD
Unit	bars	°C	-	rpm	m/min	mm
Value	20	450	3	3	5	40

Substrate: AA6082 , grit blasted #24

Particle impact velocity ≈ 580–620 m/s

HIGH PRESSURE COLD SPRAYING: COATINGS CHARACTERISTICS





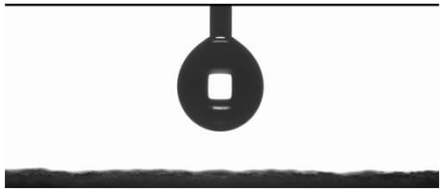
WETTABILITY OF CS AL-QC COATINGS

J Therm Spray Tech
https://doi.org/10.1007/s11666-022-01522-w

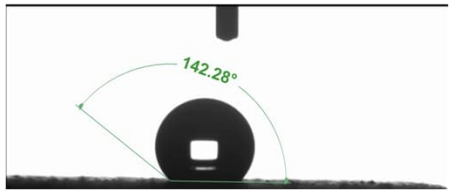
PEER REVIEWED

Wetting Behavior and Functionality Restoration of Cold-Sprayed Aluminum-Quasicrystalline Composite Coatings

Reza Jafari[1] · Jarkko Kiilakoski[2] · Mari Honkanen[3] · Minnamari Vippola[1,3] · Heli Koivuluoto[1]



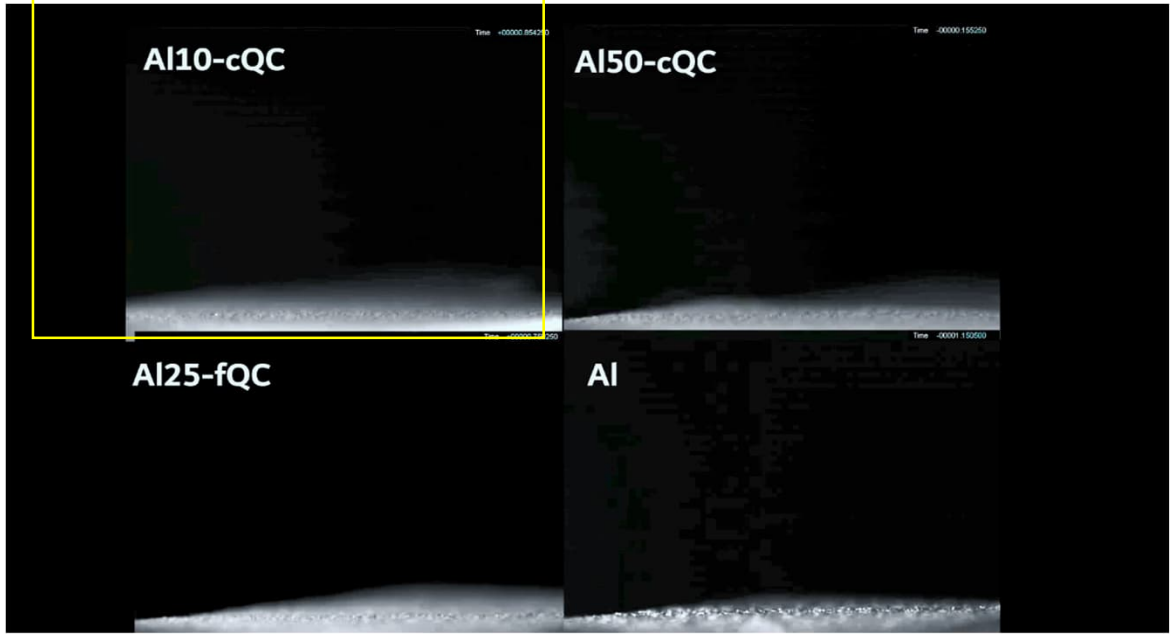
CS AA 6061



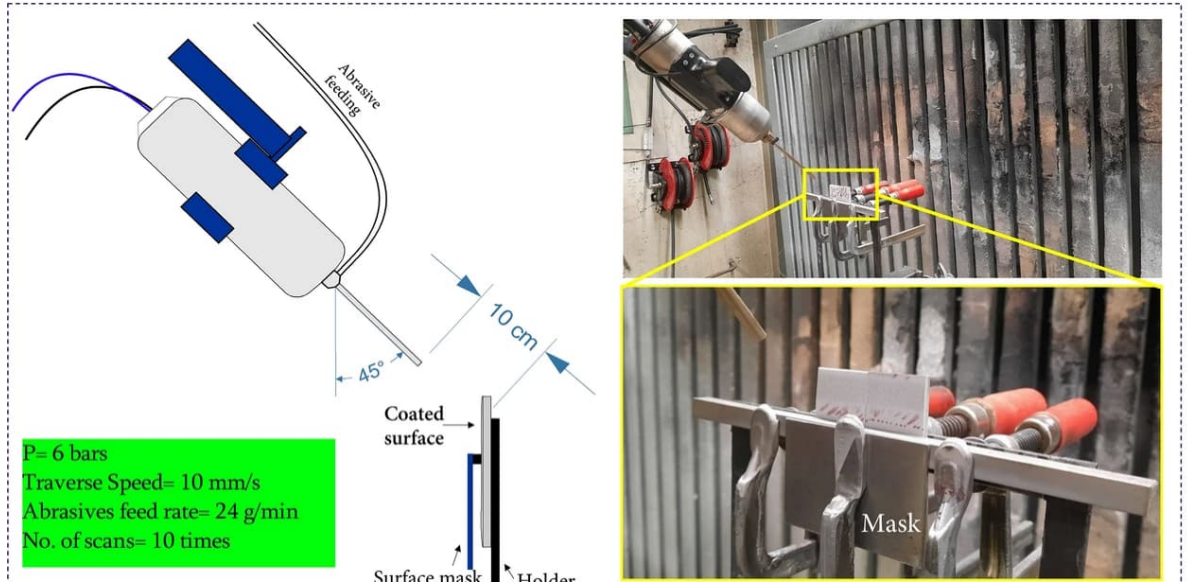
AA 6061 + 50 vol%QC

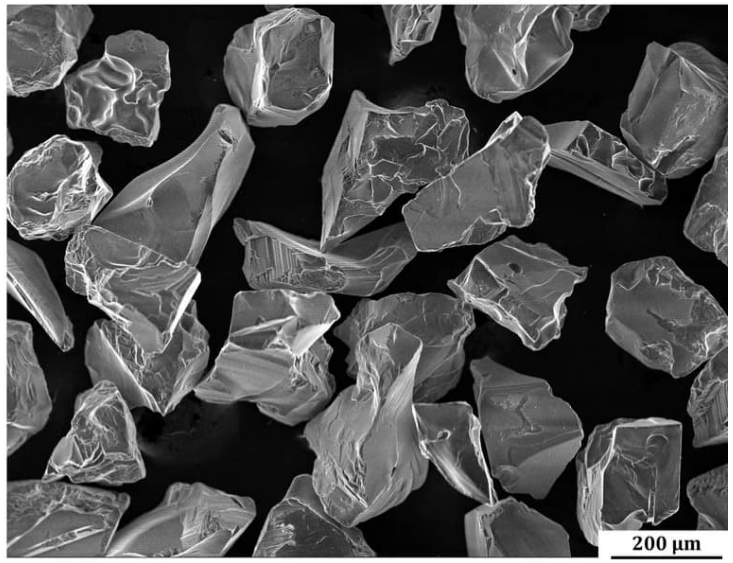
Highest QC content

AA 6061 + 90 vol%QC



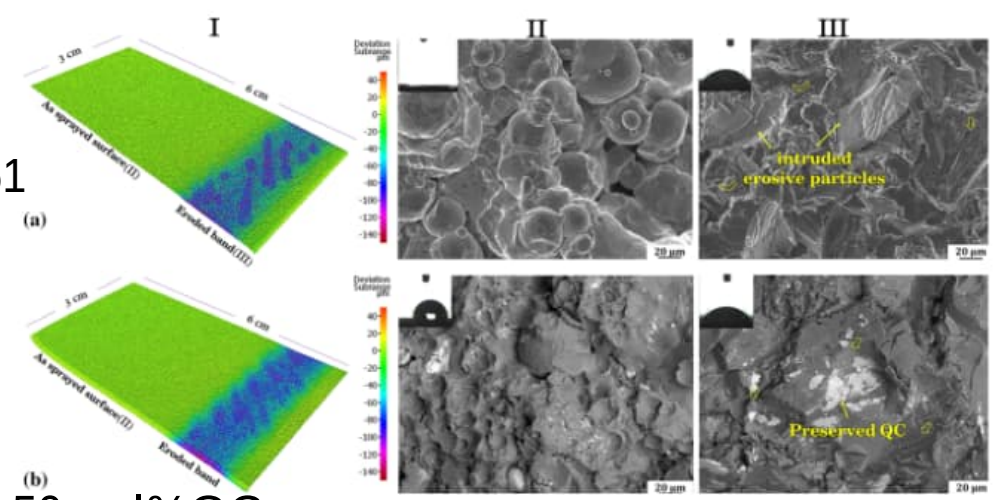
FUNCTIONALITY RESTORATION BY REPAIRING ARTIFICIAL DEFECT

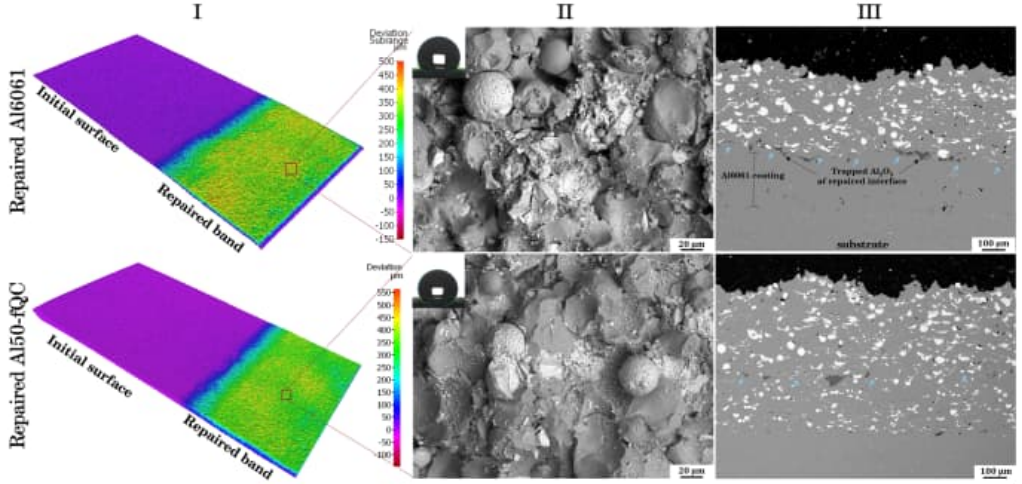




CS AA 6061

AA 6061 + 50 vol%QC

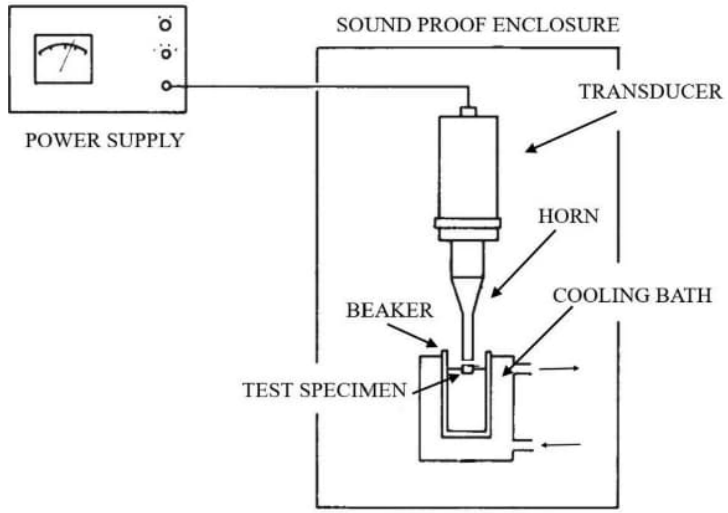


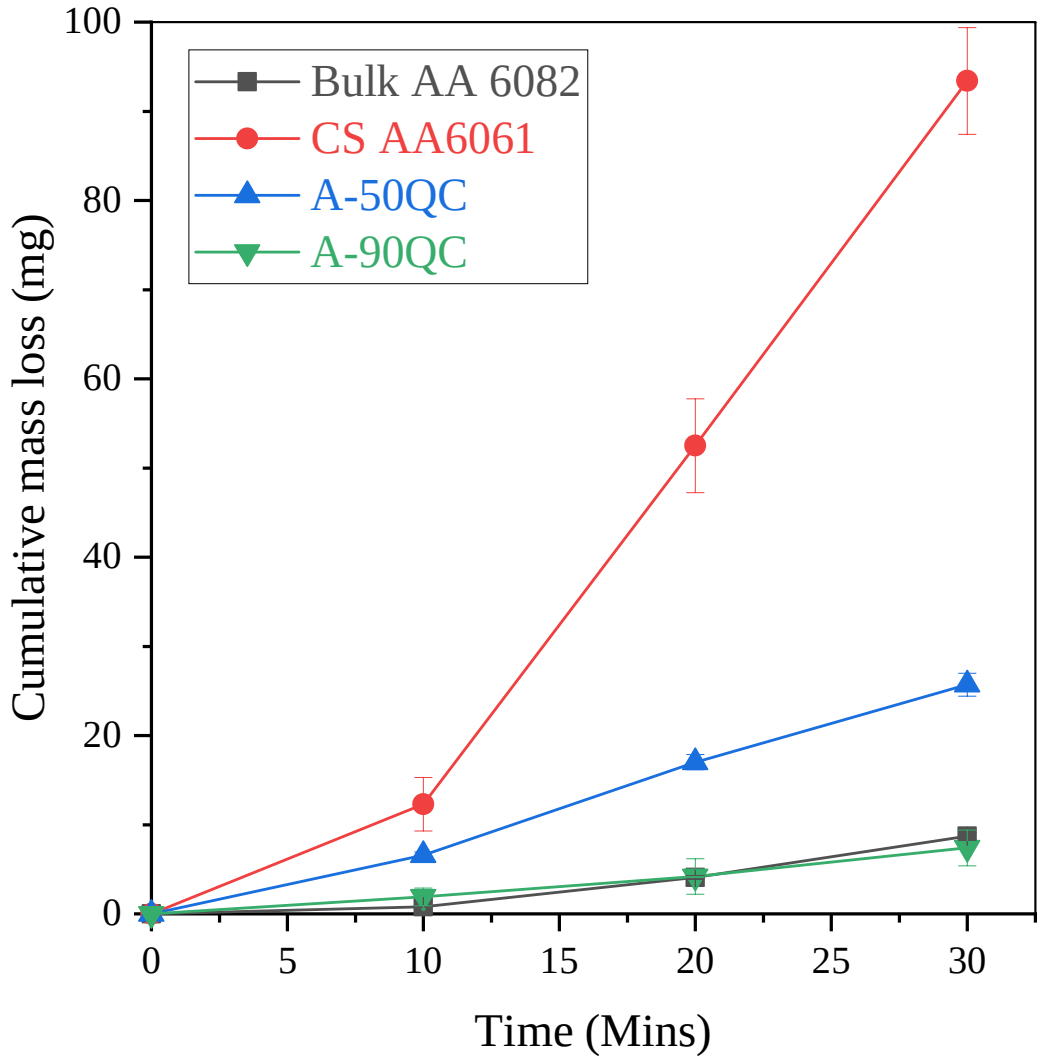


COHESION ASSESSMENT BY CAVITATION EROSION

ASTM G32-21 "standard test method for cavitation erosion using vibratory apparatus".

- Vibrating tip: Ti-6Al-4V
- Tip diameter : 15.9 mm.
- Frequency: 20 kHz
- Peak to peak amplitude: 50 µm
- Distance: : 0.5 mm
- Pure water temperature: 25 °C
- Test specimen surface condition: Polished





Koivuluoto H, et. Al.. Microstructural analysis of high-pressure cold-sprayed Ni, NiCu and NiCu + Al2O3 coatings. Surface and Coatings Technology. 2015;268:224-229.

COHESION ASSESSMENT BY CAVITATION EROSION: OPTICAL PROFILOMETRY

Cavitation time

0 min

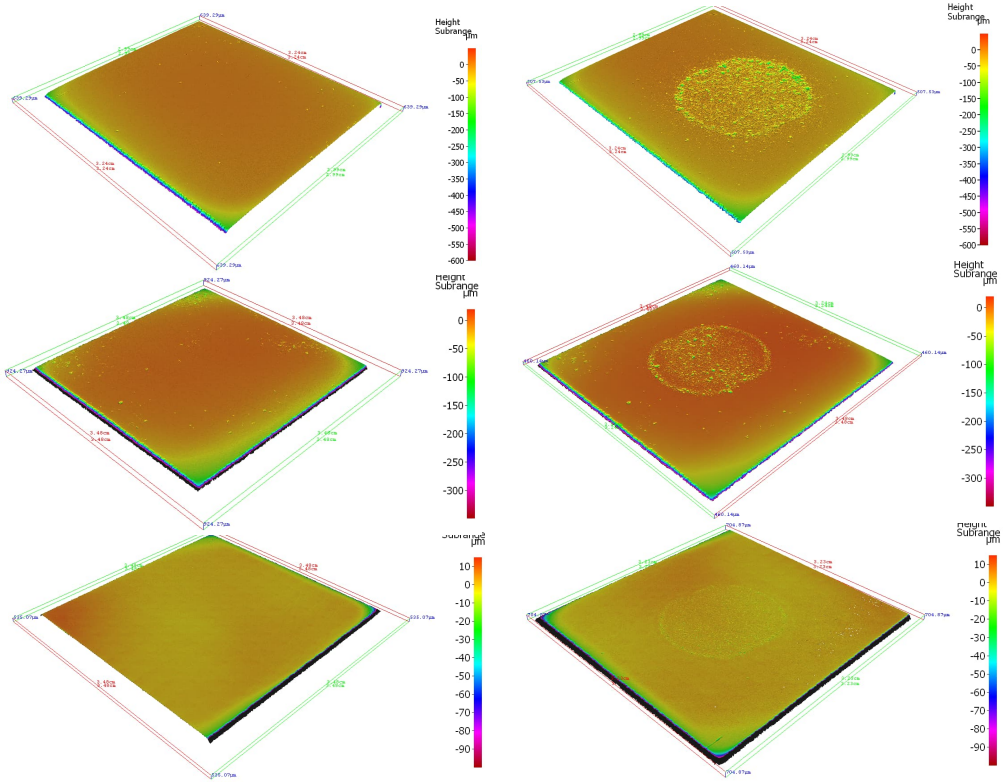
10 mins

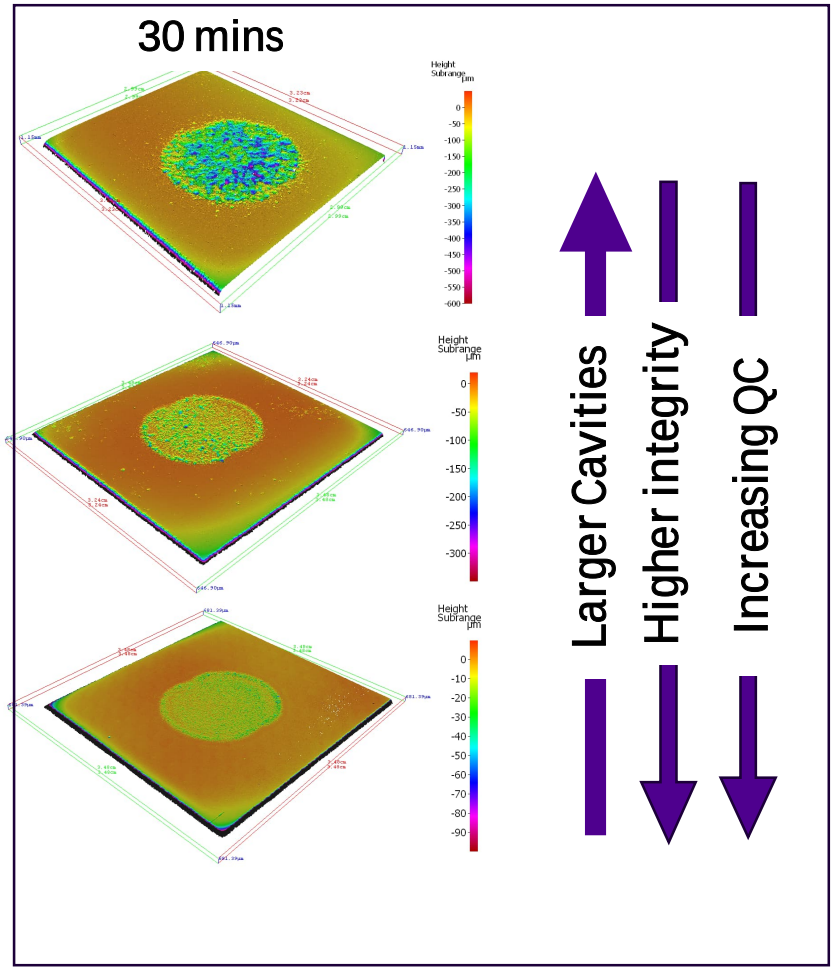
30 mins

CS AA6061

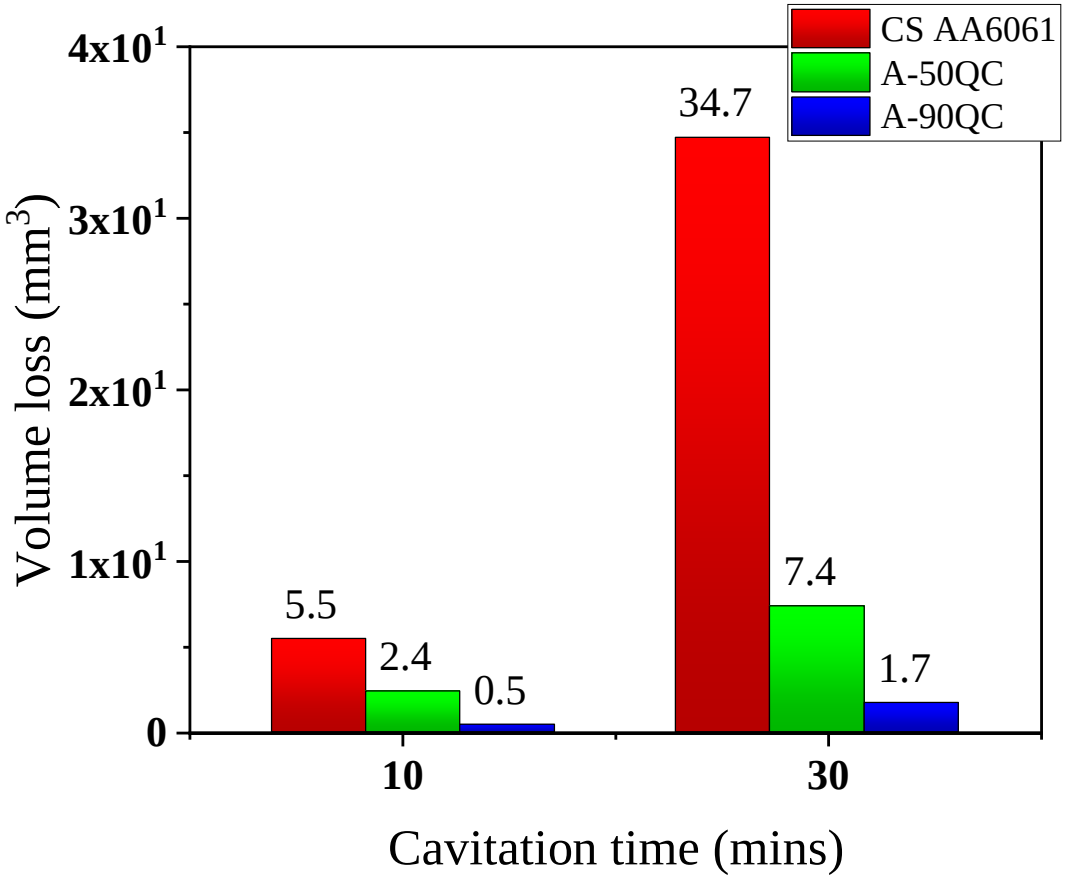
CS AA6061 + 50 vol% QC

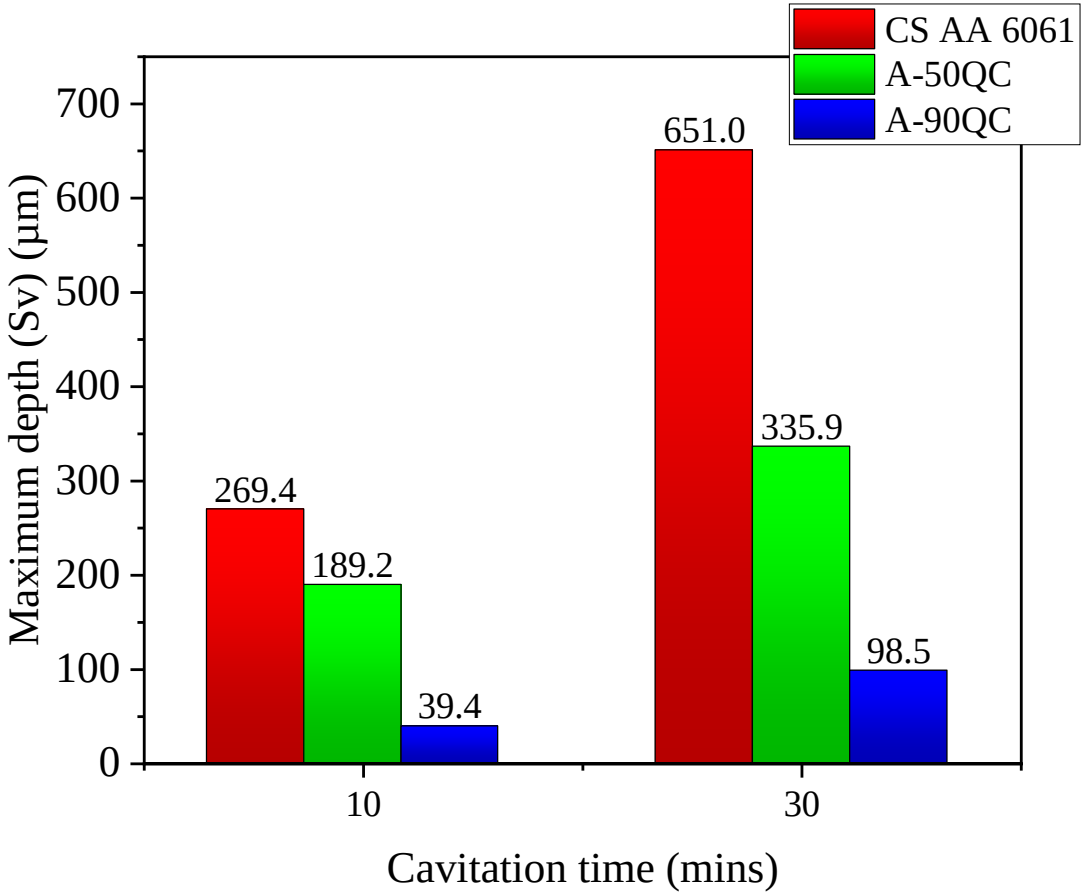
CS AA6061 + 90 vol% QC





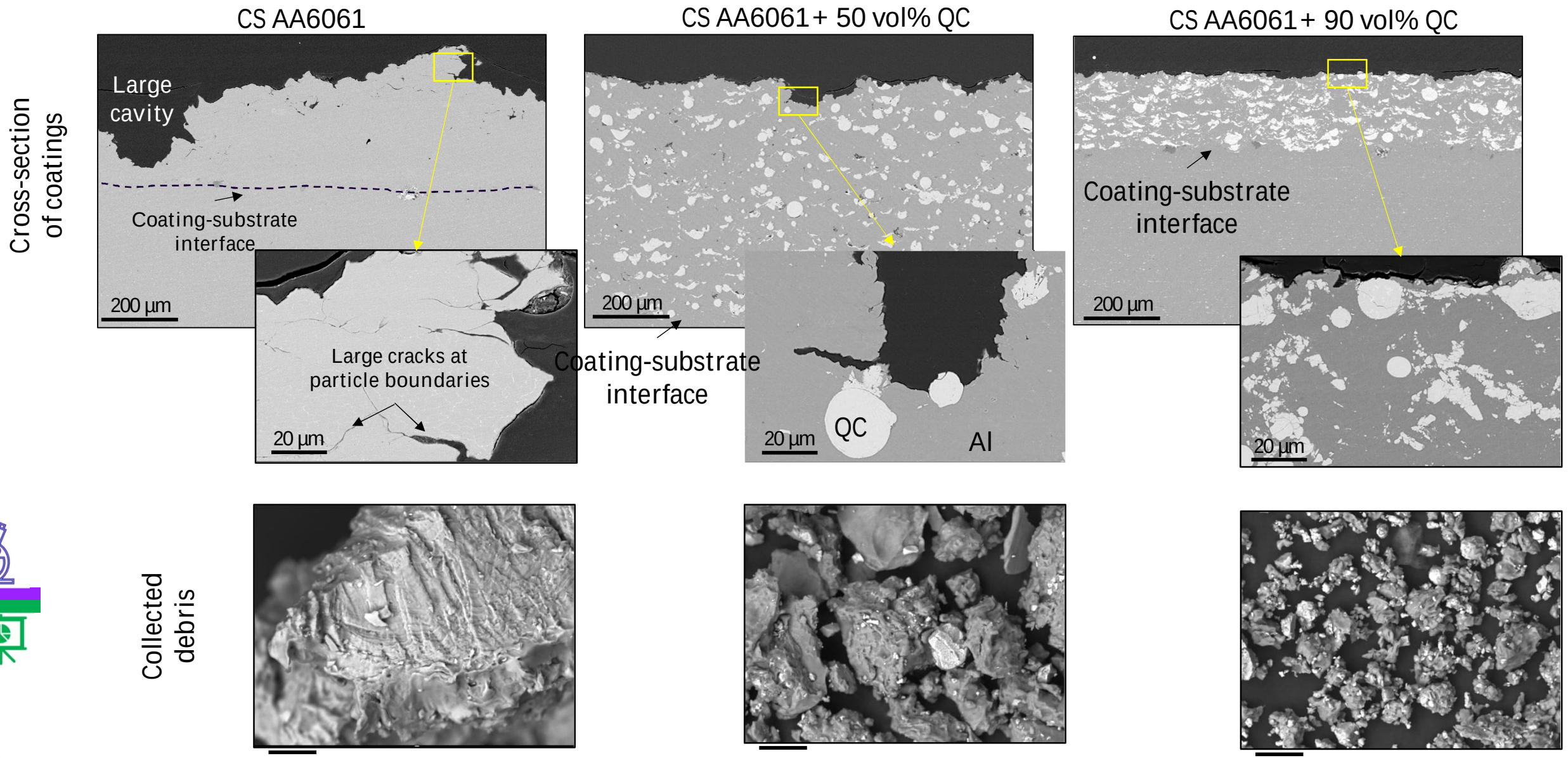
COHESION ASSESSMENT BY CAVITATION EROSION: OPTICAL PROFILOMETRY



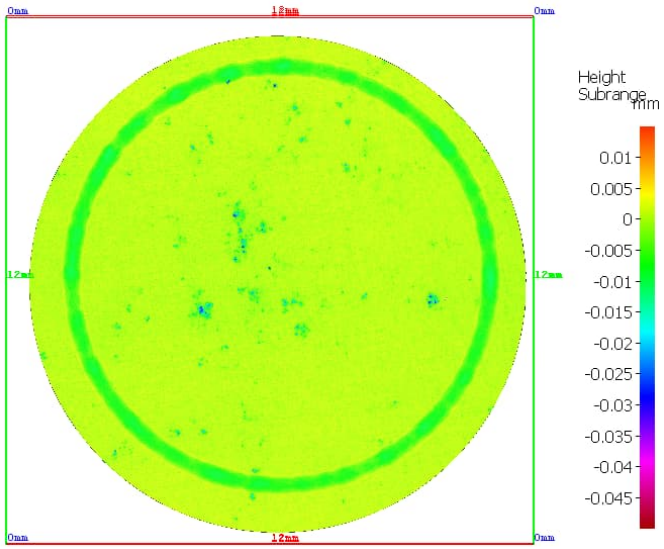


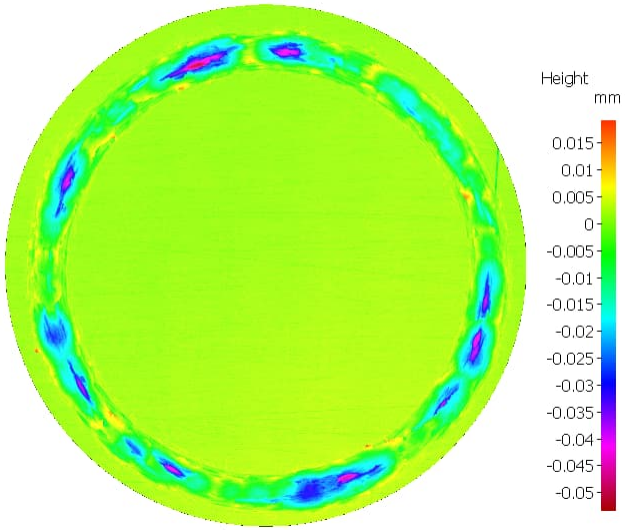
- Less volume loss and reduced the maximum depth of damage by increasing QC in the structure

MICROSTRUCTURE OF CS COATINGS AFTER 30 MINS CAVITATION EROSION



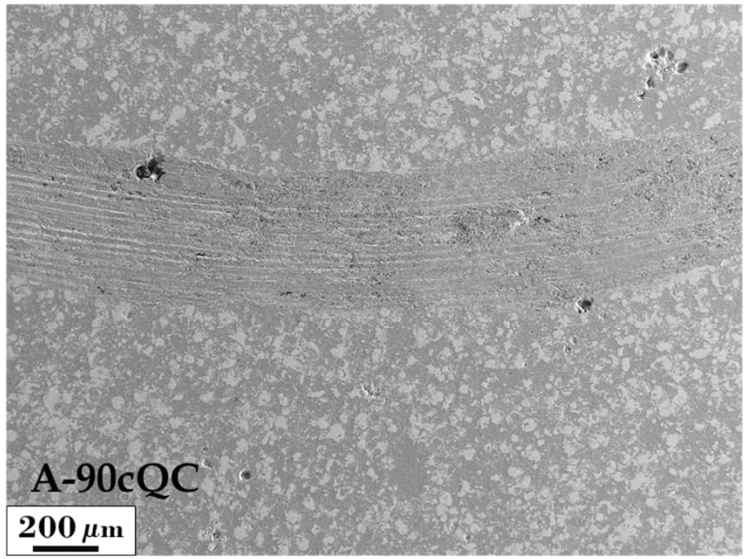
WEAR TRACK ANALYSIS

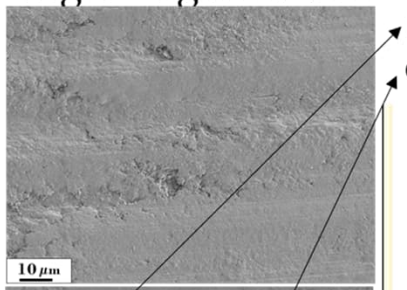


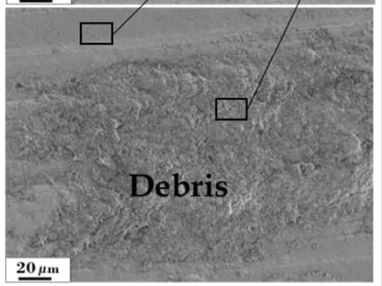


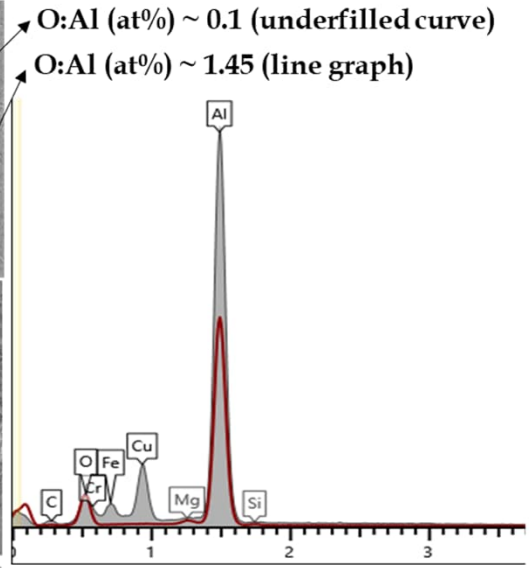
Overall View

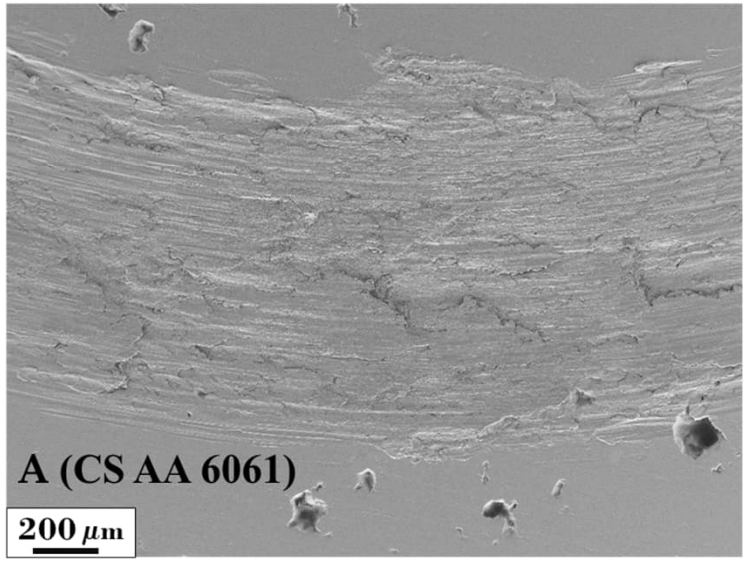
High Magnification

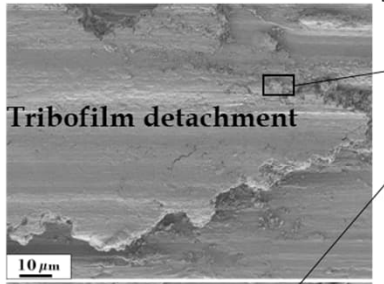


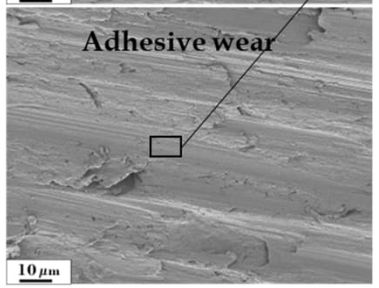


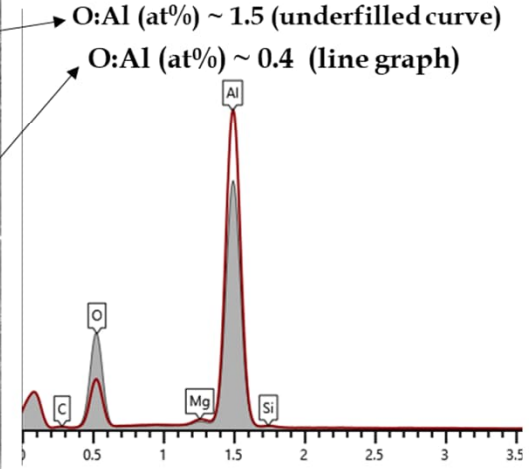




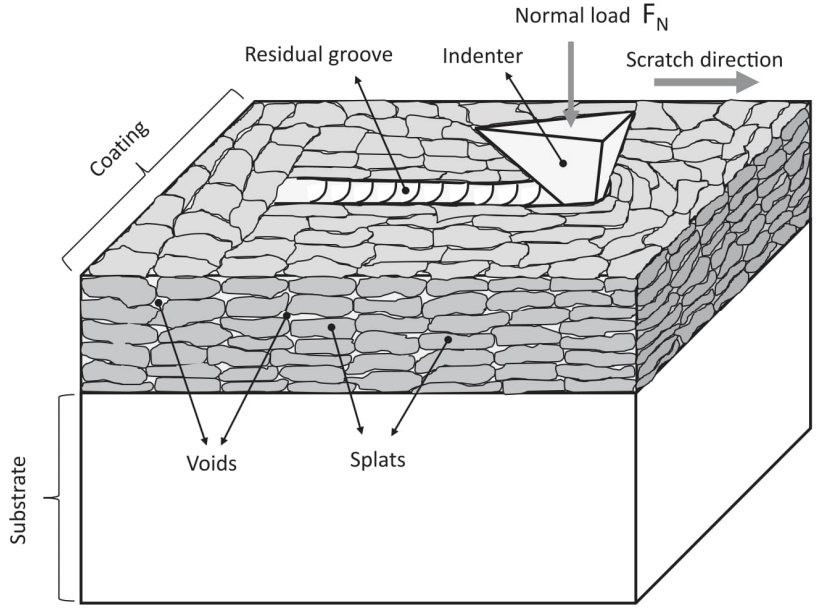








SCRATCH TESTING ON CS AL-BASED COATINGS

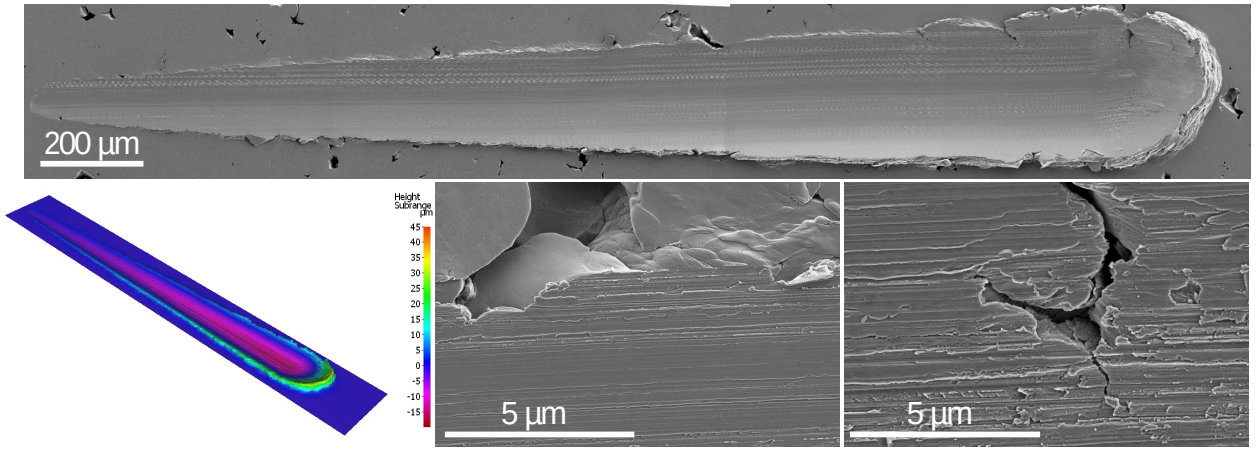


Courtesy of: Poza P, Garrido-Maneiro MÁ. Progress in Materials Science. 2022;123:100839

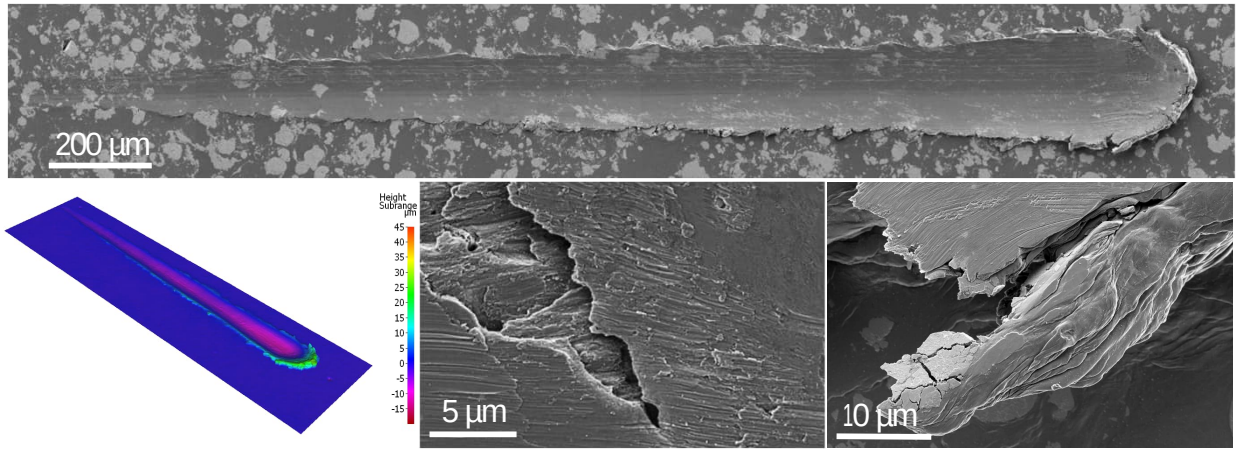
Procedure

Scratch length: 2 mm
Sliding Speed: 0,01 mm/min
loads: Linear increasing load 2-20N
Indenter: Rockwell C Diamond
Surface finish: EBSD
Load cell: 200N

CS AA 6061

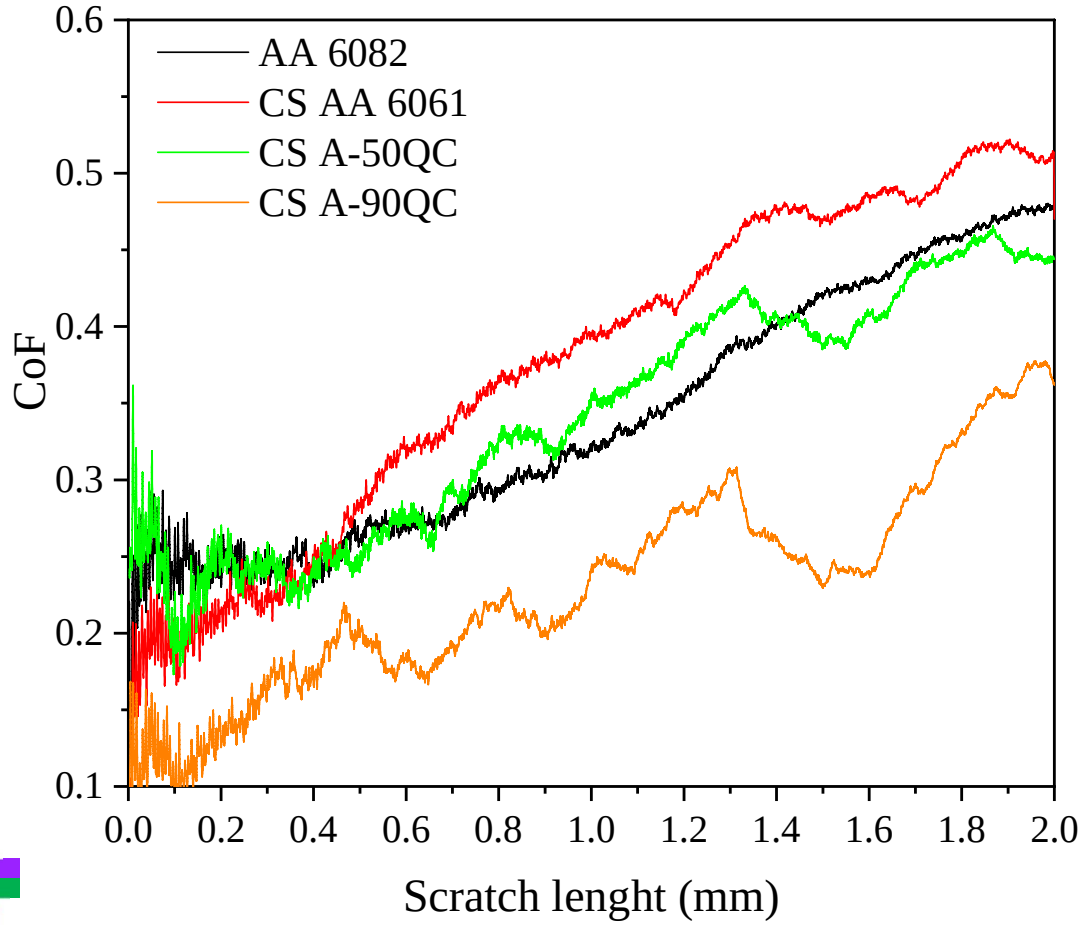


CS AA6061 + 90 vol% QC



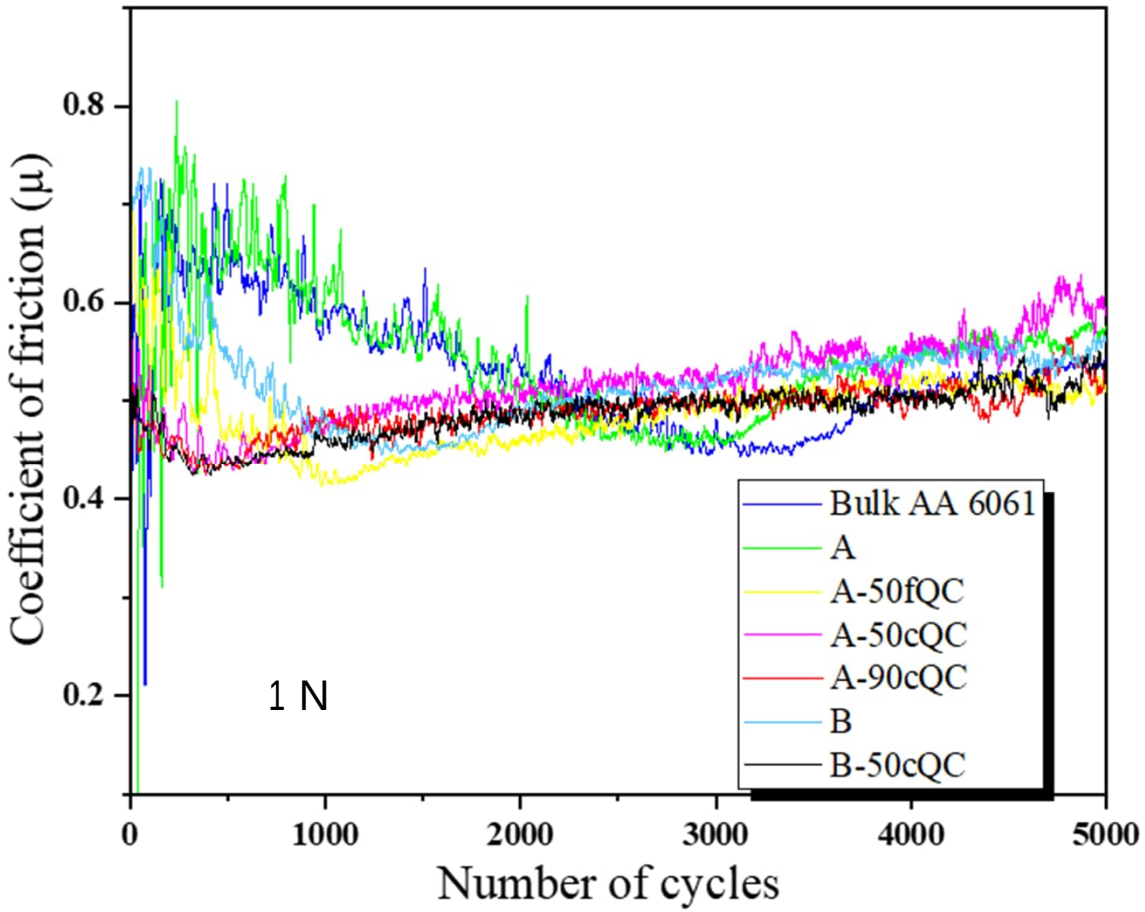
SCRATCH TESTING ON CS AL-BASED COATINGS

Scratch test by a diamond indenter



2 N to 20 N Load Ramp

Ball on disc sliding wear test (Alumina ball)



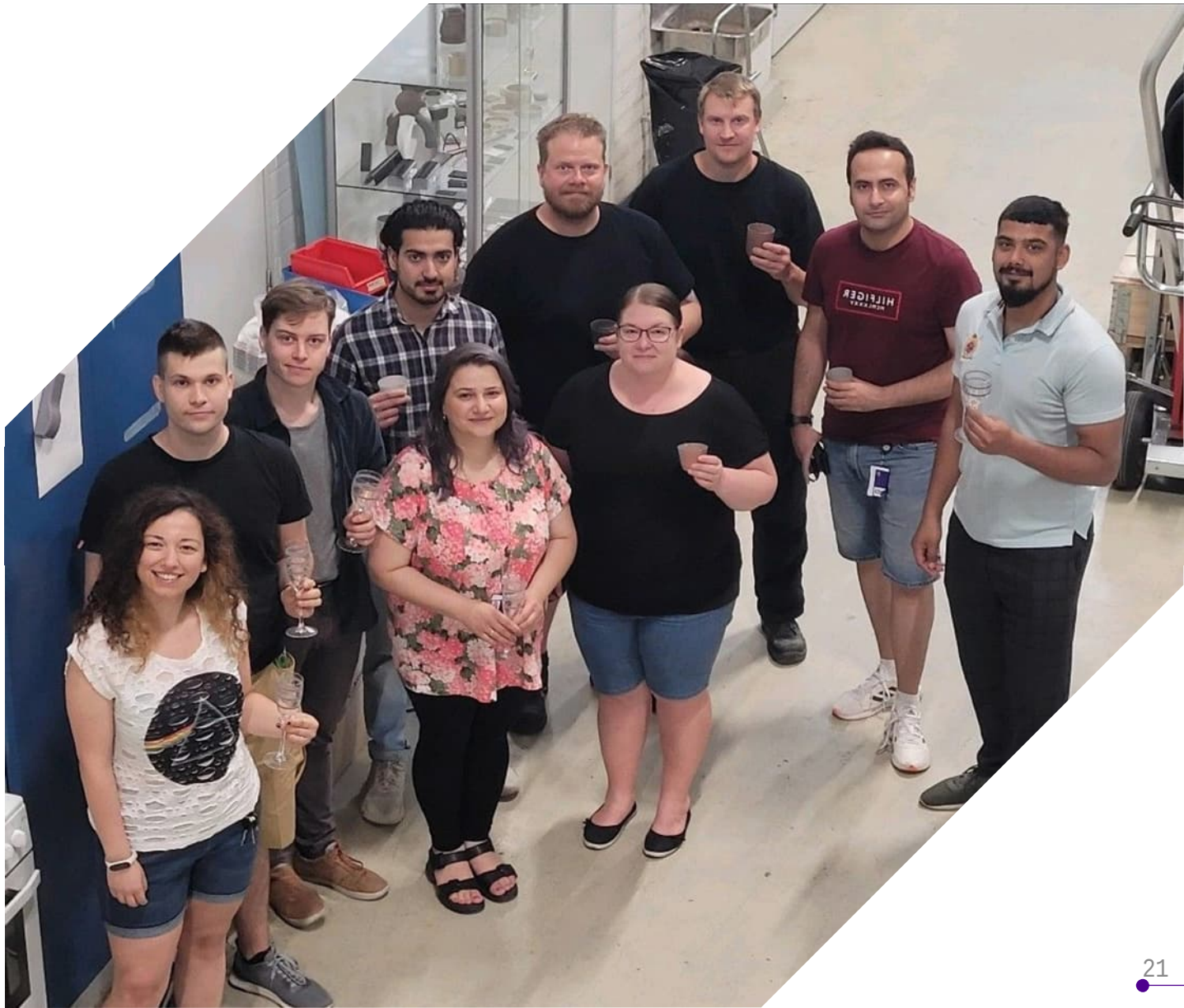
Jafari R, et al. Tribological assessment of cold sprayed aluminum-quasicrystal composite coatings. In: ITSC 2023. ASM International; 2023.

CONCLUSIONS

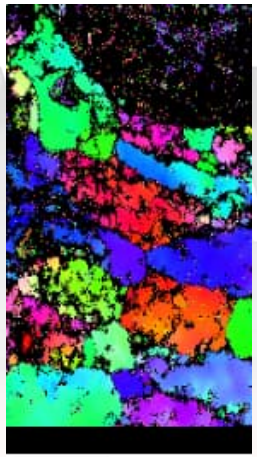
- Successful QC-reinforced composite coating fabrication by cold spraying
- Enhanced cohesion and microstructural integrity of sprayed coatings are achievable by QC incorporation, proportional to the reinforcement content
- The properties of cold-sprayed Al-QC deposits are inherited from their microstructure and state of deformation.
- CS Al-QC and composites exhibited enhanced functionality (Tribological properties with acceptable durability, enhanced mechanical properties and integrity of the coating structure)

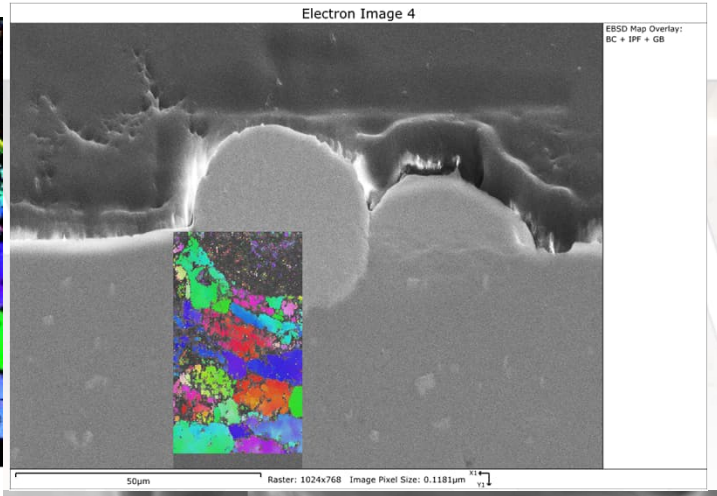
ACKNOWLEDGEMENT

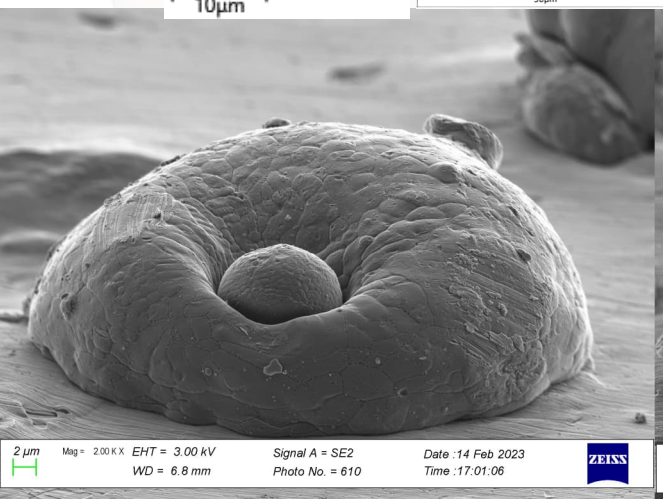
- Jarkko Lehti and Anssi Metsahonkala for spraying of the coatings
- Dr. Jarkko Kiilakoski and Mr. Dominque Billieres from SaintGobain Coating Solution
- Tampere Microscopy Center and its staff, for technical support and providing the infrastructure for the microstructural characterization
- Prof. Jan Cizek and his colleagues from Institute of Plasma Physics (Prague)

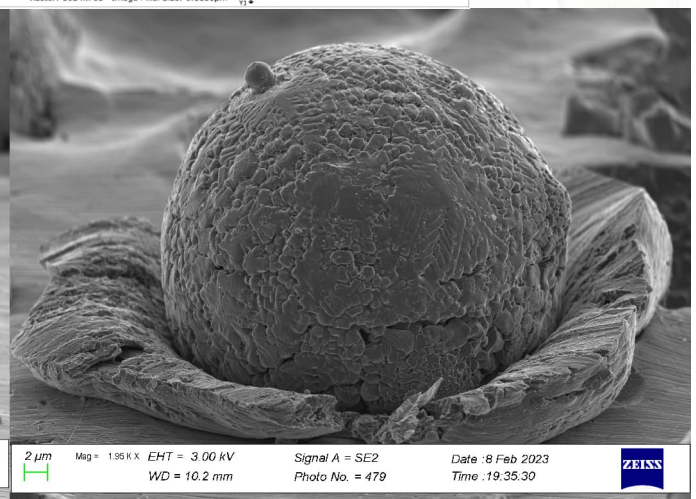


THANK YOU!









Be in touch

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