Influence of Post-treatment on the Tribo-mechanical properties of Cermet Coatings

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HIPing Post-treatment – Previous Investigations

1) Kuribayashi, H., Suganuma, K., Miyamoto, Y., & Koizumi, M., "Effect of HIP treatment on plasma sprayed coating onto stainless steel", American ceramic society bulletin, 65(9), 1306-1310, (1986).

Al_2O_3, ZrO_2 and TiC plasma spray coatings HIPed (Capsulated) at 1100 to 1300°C for 1hour at 100MPa - ***Remarkable improvements in hardness and tensile strength.***

2) H. Ito, Nakamura, R., Shiroyoma, M., & Sasaki, T., "Post-treatment of plasma sprayed WC-Co coatings by hot isostatic pressing", NTSC, CA, 233-238, (1990).

WC-Co plasma spray coatings HIPed (Capsulated) at 500 to 1000 °C for 30 minutes at about 5MPa – ***Remarkable improvements in hardness and abrasive wear resistance. Lamellar to granular transformation.***

3) Khor, K.A. & Loh, N. L., "Hot isostatic pressing of plasma sprayed Ni-base alloys", JTST, 3(1), 57-62, (1994).

Numerous studies on Capsulated and uncapsulated HIPing of plasma sprayed NiCrAl and ZrO_2-Y_2O_3 coatings – ***Improvement in hardness and modulus, reduction in porosity.***

Project Background

S. Tobe, Y. Ando, R. Ahmed and *V. Stoica,* "Enhancement of wear and mechanical properties of thermally sprayed WC-Co coatings by HIPing post-treatment", Tribology in Environmental Design, Second International conference, Bournemouth, UK, ISBN 1 860584152, 119-127, 2003.

HIP Code	HC-1	HC-2	HC-3	HC-4	HC-5	AS
Capsulation	Yes	No	Yes	Yes	Yes	As-Sprayed (Not HIPed)
Temperature (°C)	850	850	900	900	1000	
Pressure (MPa)	150	150	150	150	150	
Holding Time (minutes)	60	60	60	120	60	

Project Background (WC-Co coatings)

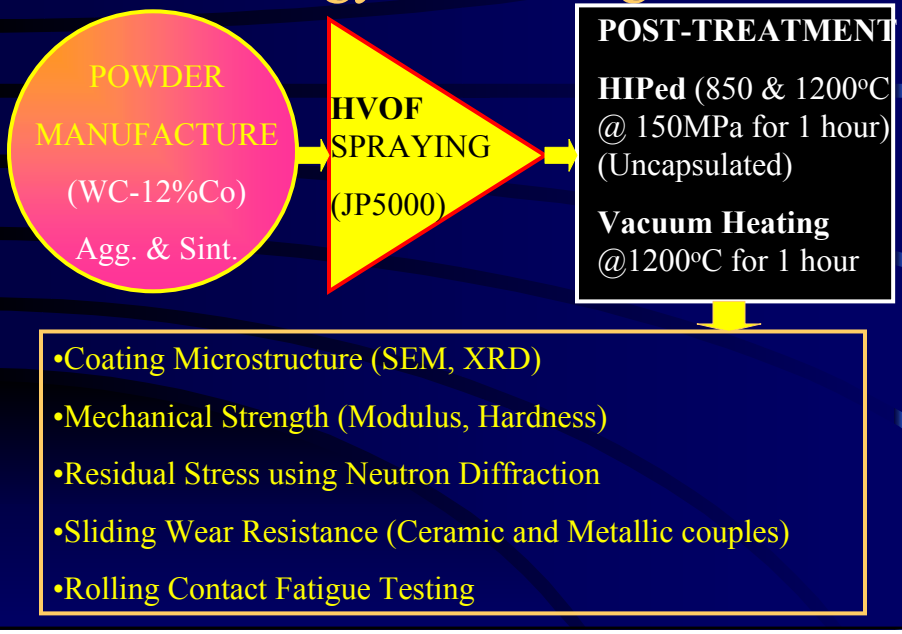
As-Sprayed Coating | HIPed @800°C (Capsulated) | HIPed @800°C (Not Capsulated)

HIPed @900°C (Capsulated) | HIPed @900°C (Capsulated) | HIPed @1000°C (Capsulated)

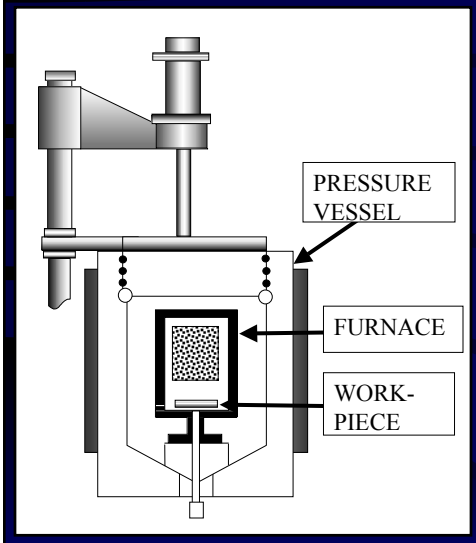
Aims of Current Investigation

- Consider Economical and Design Factors
- Higher Temperatures?
- Influence of pressure? (HIPing vs. VHT)
- Develop structure property relationship for tribo-mechanical applications

Methodology of Investigation



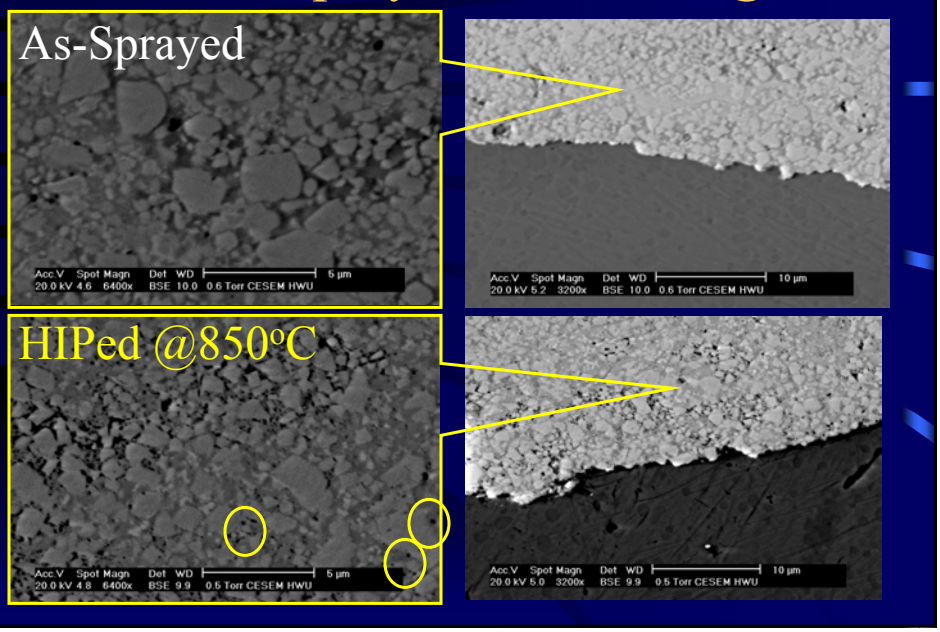
Hot Isostatic Pressing Unit



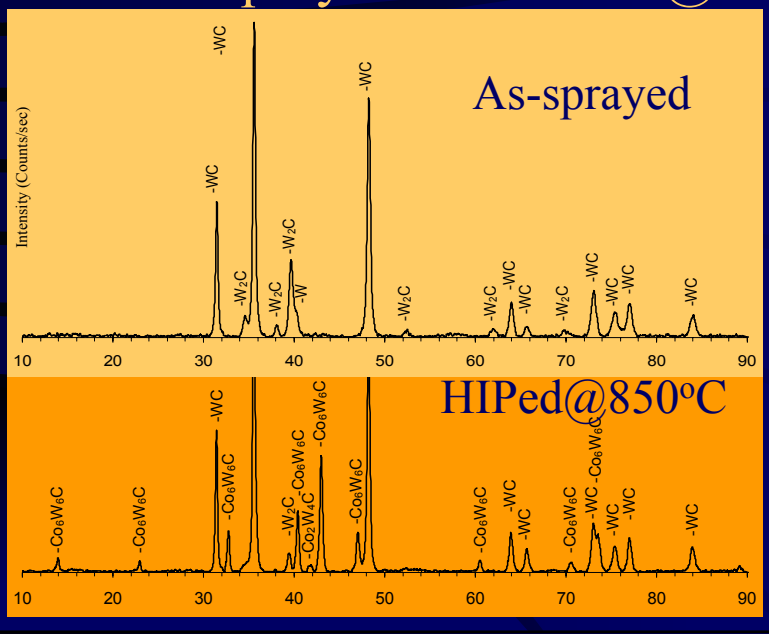
HIPing Conditions

Temperature	850 °C , 1200 °C
Pressure	150 MPa
Environment	Argon
Heating /Cooling rate	4 °C /minute
Encapsulation	No

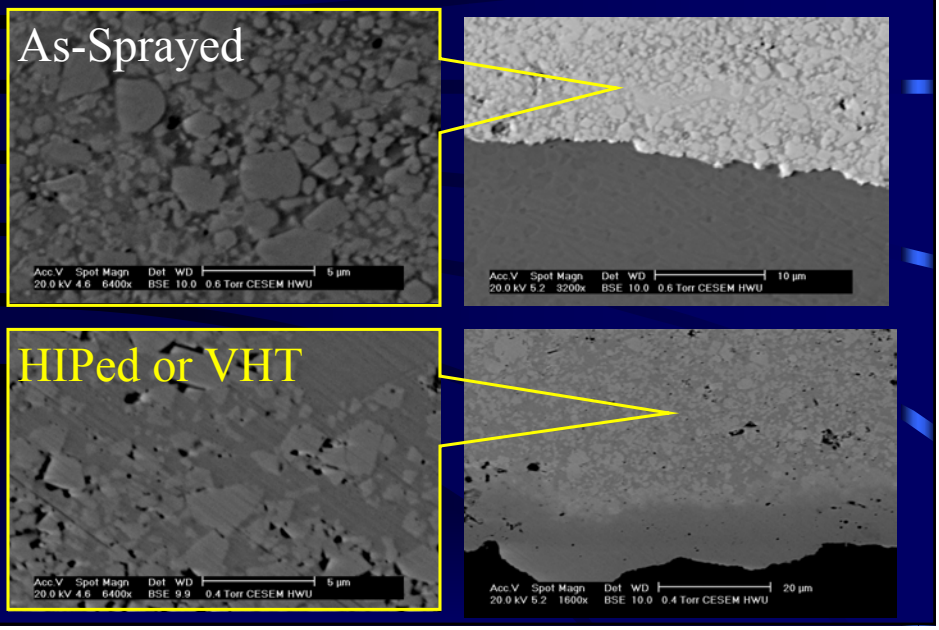
SEM – As-sprayed vs. HIPed@850°C



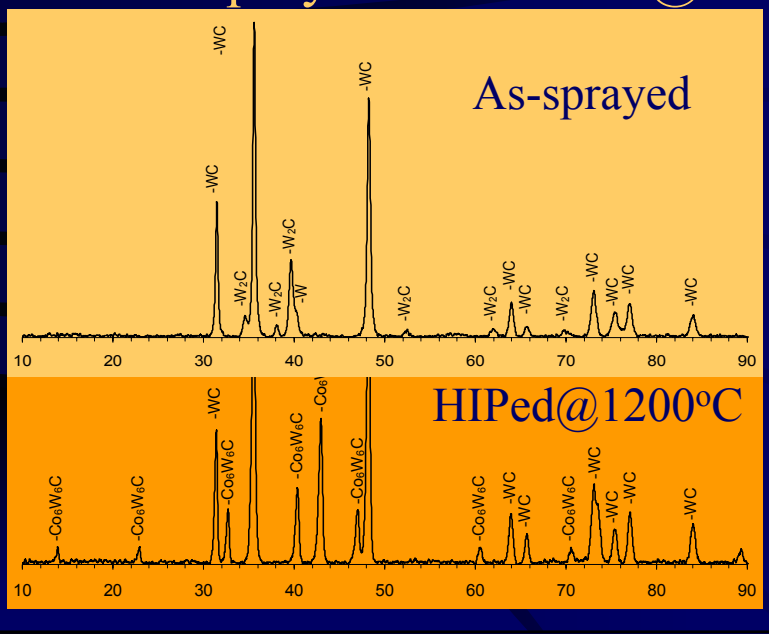
XRD – As-sprayed vs. HIPed @850°C



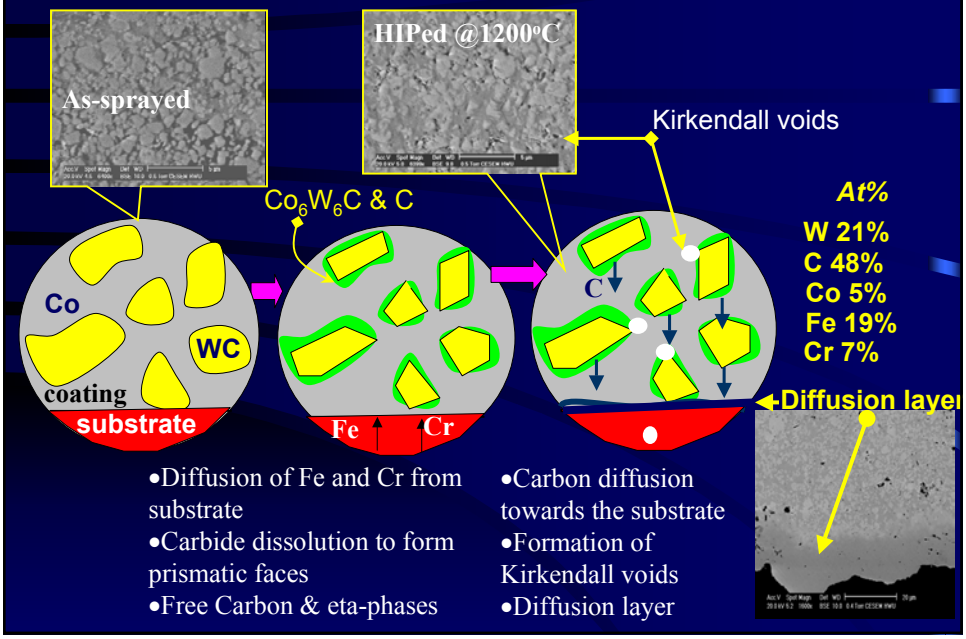
SEM – As-sprayed vs. HIPed or VHT @1200°C



XRD – As-sprayed vs. HIPed @1200°C



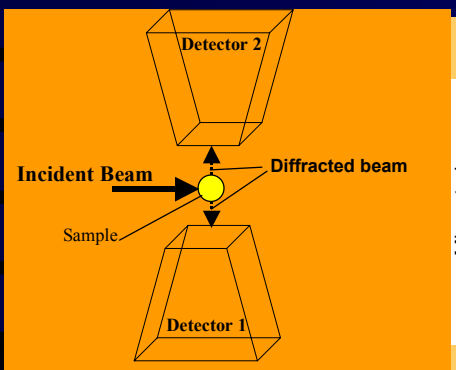
Microstructural Changes -Summary



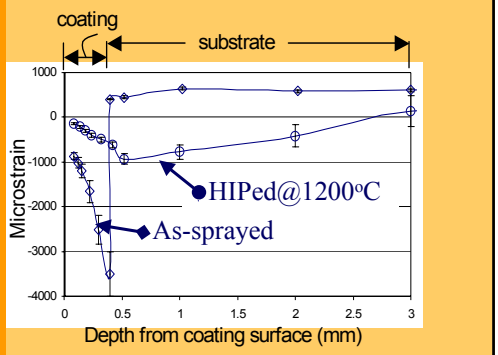
- Diffusion of Fe and Cr from substrate
- Carbide dissolution to form prismatic faces
- Free Carbon & eta-phases

- Carbon diffusion towards the substrate
- Formation of Kirkendall voids
- Diffusion layer

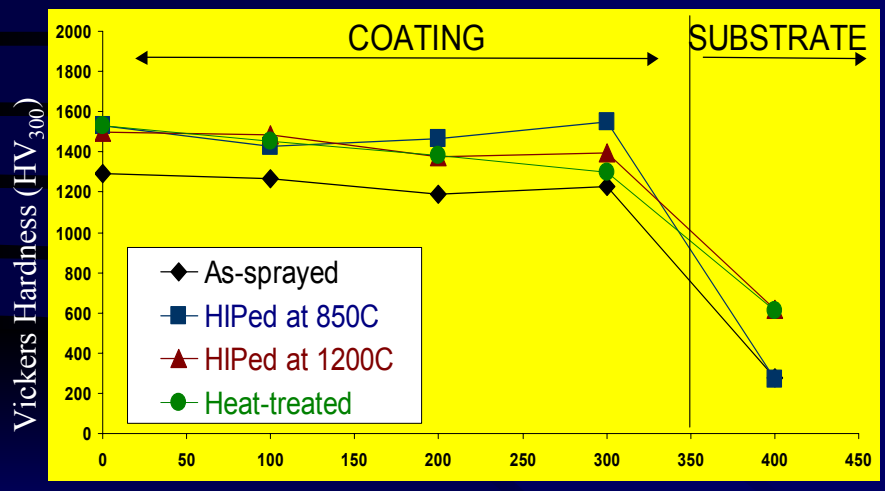
Residual Strain –Neutron Diffraction



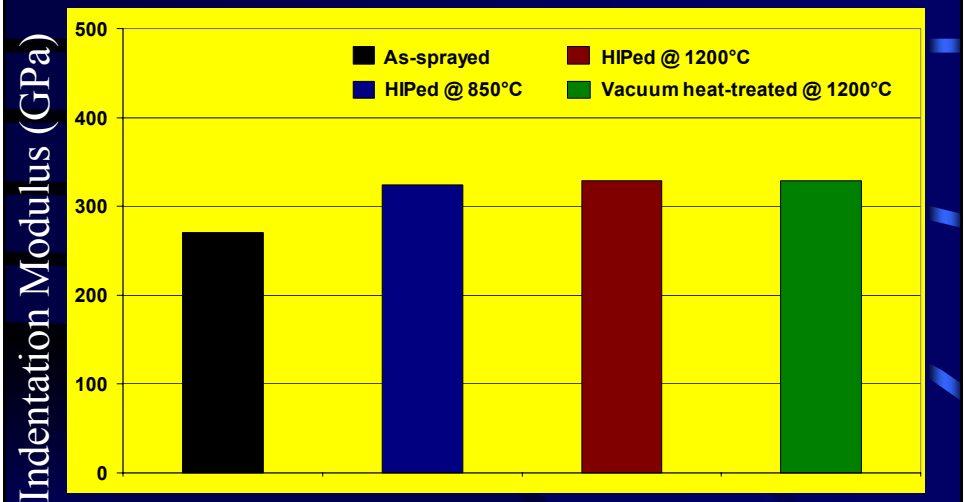
ISIS Facility Set-up, UK



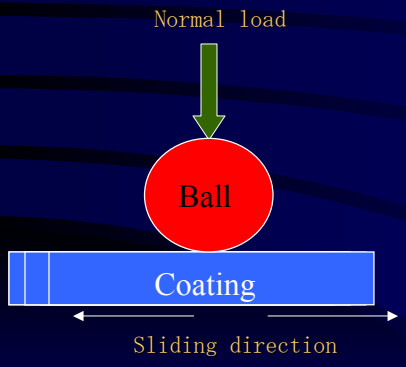
Hardness Comparison



Indentation Modulus = $E(1-\nu^2)$



Sliding Wear Tests

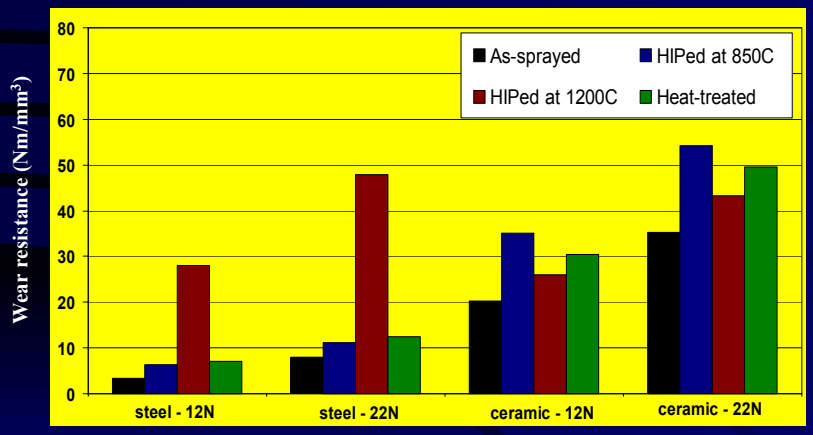


Test conditions

Counter Body (balls)	440C Steel Si_3N_4 ceramic
Load	12 and 22 N
Sliding Speed	0.012m/s
Lubrication	Dry

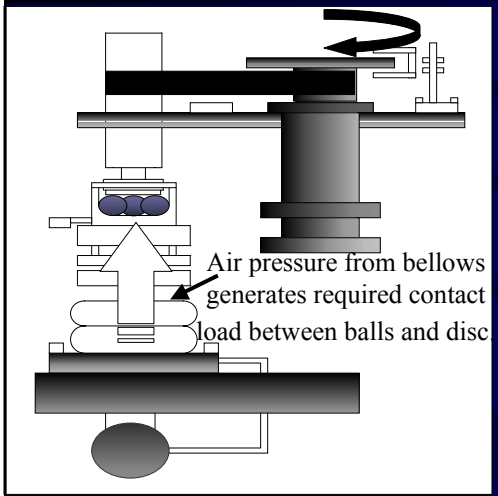
Reciprocating ball on plate apparatus

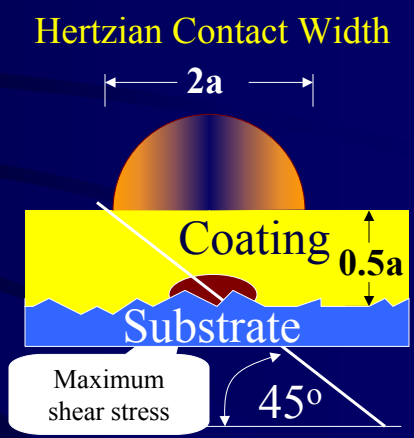
Wear Performance - system



Rolling Contact Fatigue Tests

Drive shaft connected via belt to motor rotates coated disc at 4000 rpm

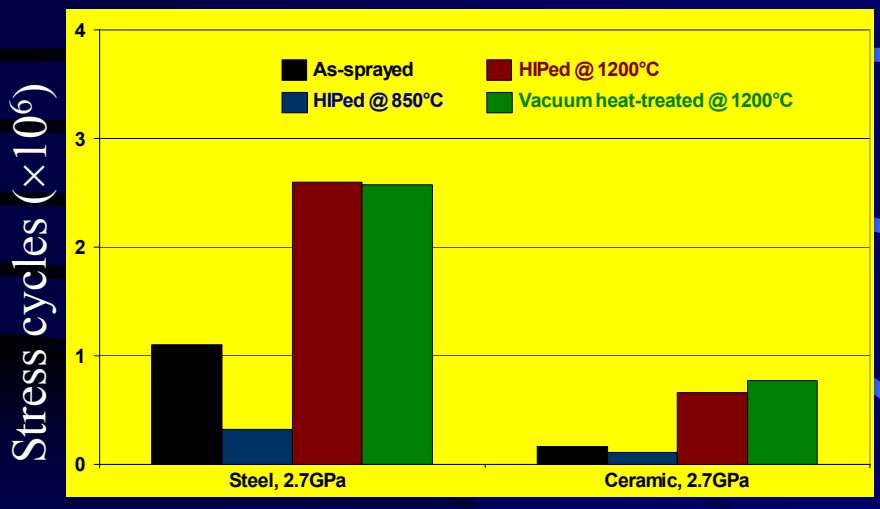




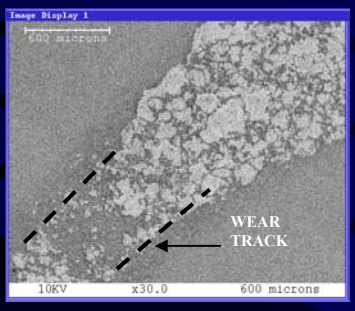
RCF Test Conditions

Planetary Balls	Steel / Ceramic
Temperature	25 °C
Hertzian Contact Stress	2.7 GPa
Lubricant Boundary Regime	Full Film

RCF Test Results



RCF Failure Modes



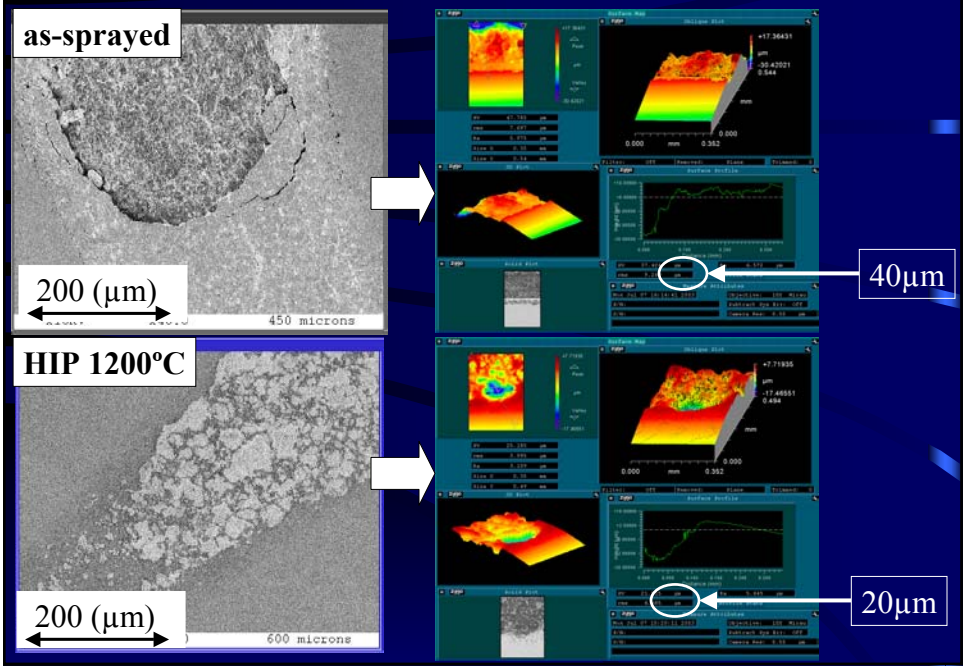
HIPed@1200°C

Progressive and Predictable Failure

Vacuum heated@1200°C

Catastrophic Failure

Post RCF Test Analysis



Conclusions

1. Microstructural changes associated with the post-treatment of WC-Co coatings can significantly improve tribo-mechanical performance of components by improving the hardness (phase changes), cohesive strength (interlamellar bonding) and adhesive strength (diffusion zone) of coatings.
2. Improvement in RCF performance was attributed to the diffusion at the coating substrate interface resulting in metallurgical bonding.
3. Sliding wear test results indicate that the overall wear resistance improves with the post-treatment, and best results were obtained for coatings HIPed at 850^{o}C for ceramic and at 1200^{o}C for steel counterbody.
4. Residual stress investigations confirmed that not only the post-treated coatings have lower and more uniform compressive strain, but also the strain gradient at the coating substrate interface is minimised after the post-treatment.

Acknowledgements

- S. Davies at Bodycote HIP, UK (HIPing)
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