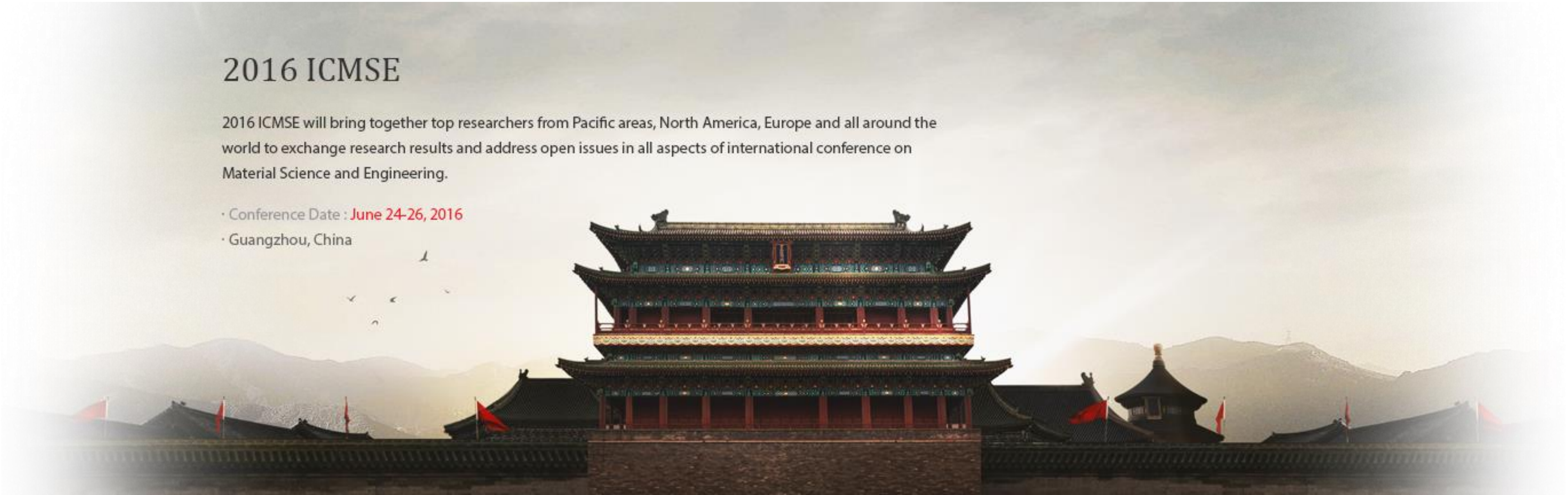
Microstructural Characterization of Thermal Barrier Coatings Glazed by a High Power Laser

Hong Zhou[1,a*], Fei Li[2,b], Jun Wang[2,c] and Bao-de Sun[2,d]

[1]Centre for Engineering and Industrial Design, Waikato Institute of Technology, Hamilton 3240, New Zealand

[2]State State Key Laboratory of Metal Matrix Composites, Shanghai Jiao Tong University, Shanghai 200240, P. R. China

[a]zhouhong.nz@gmail.com, [b]lifei74@sjtu.edu.cn, [c]junwang@sjtu.edu.cn, [d]bdsun@sjtu.edu.cn



Dr. Hong ZHOU

Centre for Engineering and Industrial Design

Rotokauri Campus, Wintec

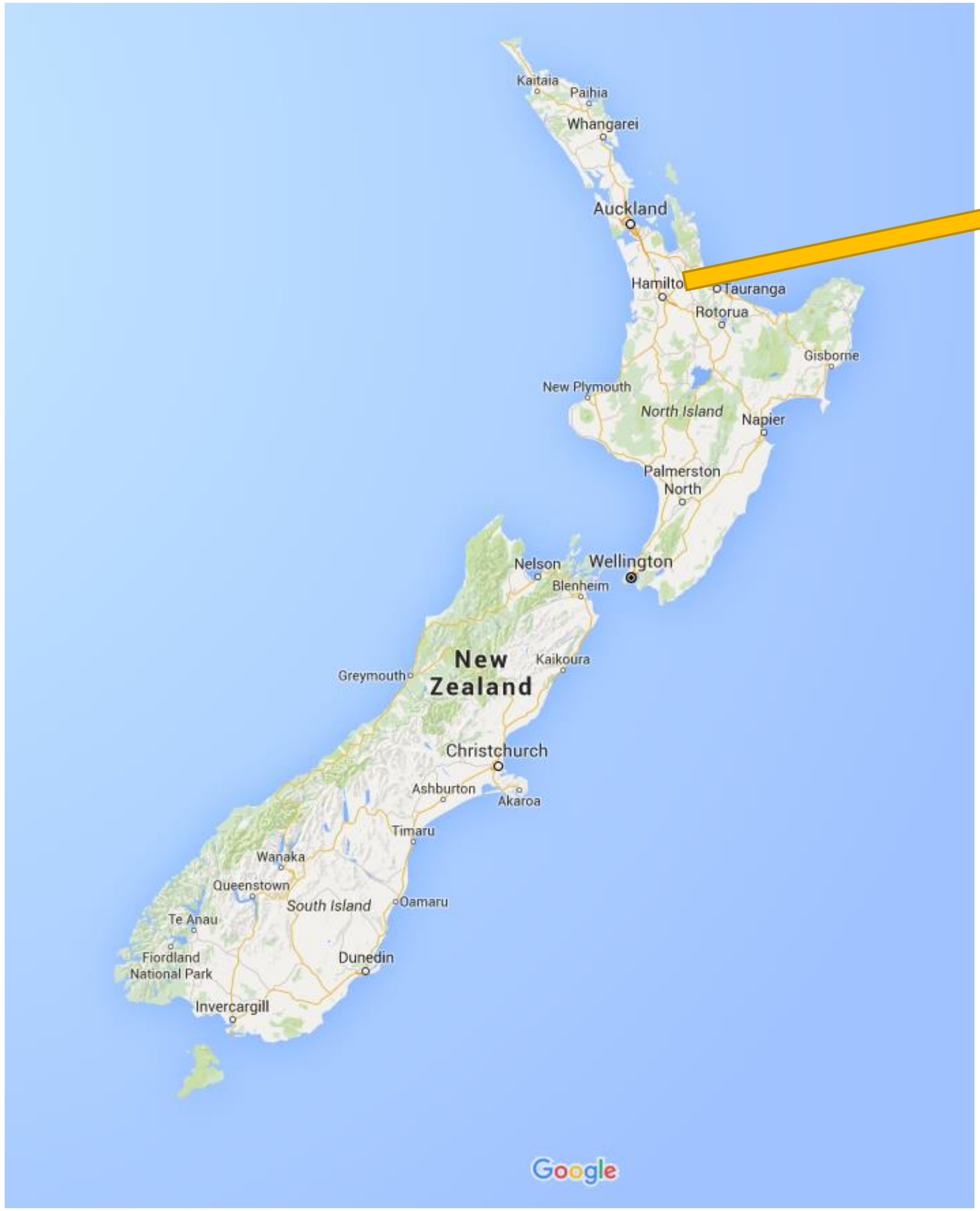
51 Akoranga Road,

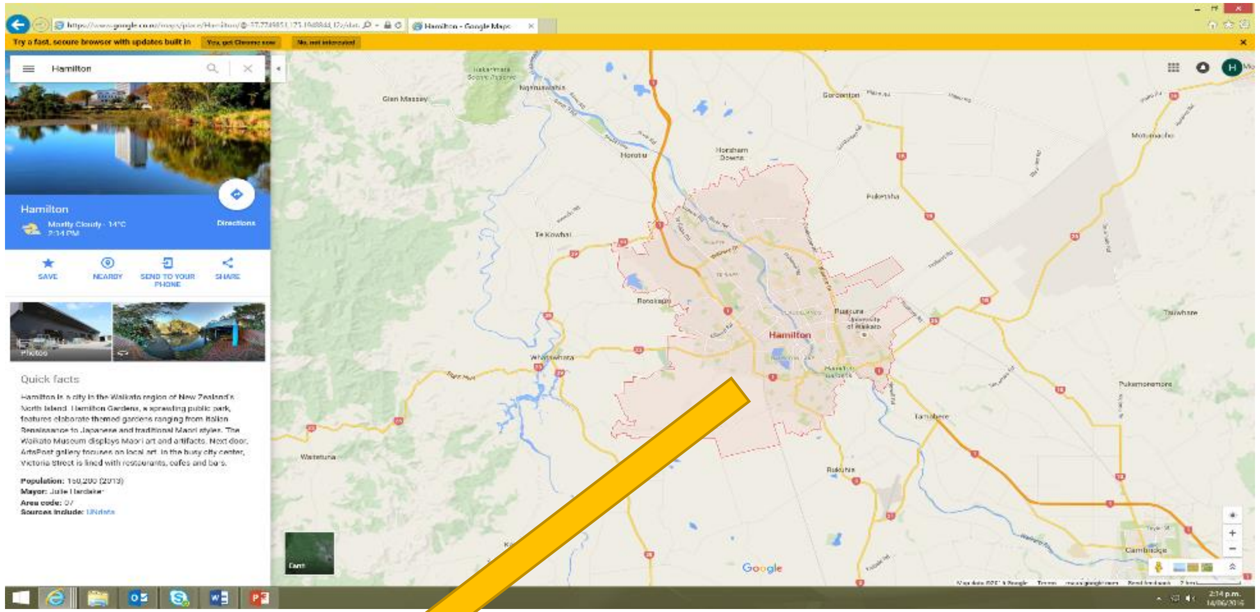
Hamilton 3200

New Zealand

Phone: +64-(0)7-834 8800 ext 3330

Email: Hong.Zhou@wintec.ac.nz





Centre for Engineering, Waikato institute of technology

2016 International Conference on Materials Science and Engineering

Wintec
WAIKATO INSTITUTE OF TECHNOLOGY
Te Kuratini o Waikato

About Wintec

oviding the skills and knowledge to build a stronger community and thousands of careers created, Wintec is ealand's largest and leading Institutes of Technology/Polytechnics (ITPs).

uses strategically located throughout the region, we are a leading provider of high quality, vocational and ducation in the Waikato region.

'll discover that you have the power to create your world, the way you want it.

Empowering you

We understand that times are changing. Although our

Plasma-sprayed duplex ZrO_2-8wt.%Y_2O_3 / MCrAlY (M=Ni and/or Co) TBCs have been widely served in industrial gas turbine engines for metallic components at high temperatures, to

- provide thermal insulation
- improve the efficiency and performance

Image @ http://www.power-technology.com/contractor_images/22313/images/203487/large/Turbine-rotor-2.jpg on 15/06/2016

Plasma-sprayed TBCs have relatively high interconnected porosity and lamina structure with splat boundaries and microcracks parallel to the interface, which are beneficial for low thermal conductivity.

However, those microstructural features bring out a low bond strength of plasma-sprayed TBCs, lead to a short thermal cycling life.

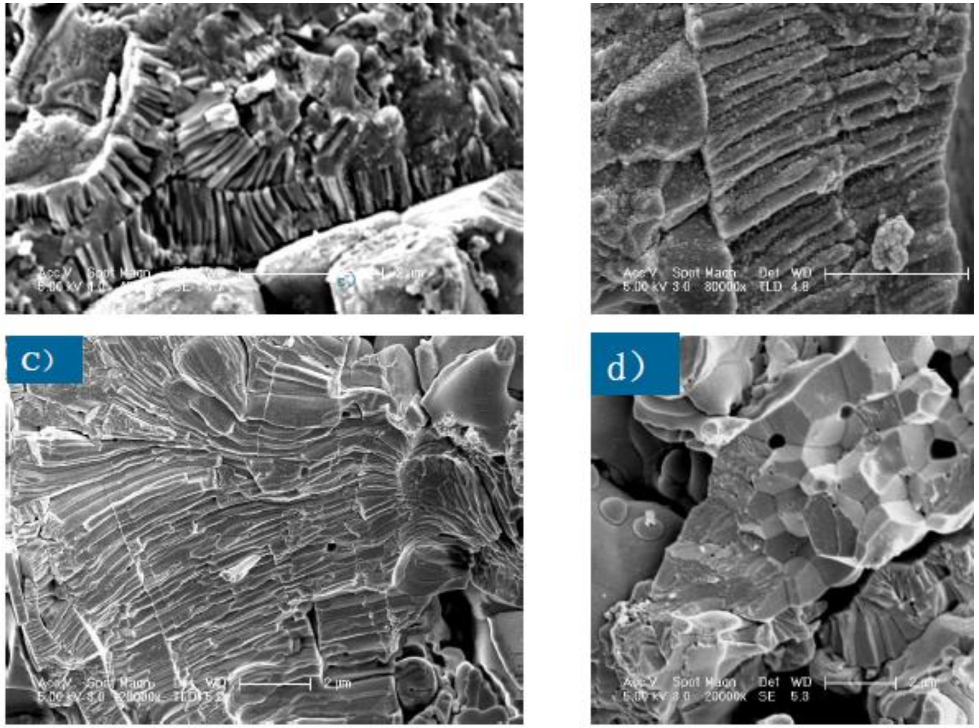


Image @ Hong’ s PhD dissertation

Lasers have been used for modification of materials surface since lasers can deliver very high energy density to a localized surface area without significantly heating up the whole body.

Laser-glazing leads to a quick remelting and subsequent rapid solidification of surface, which results in a dense top layer with new microstructure, reduced surface roughness and low porosity

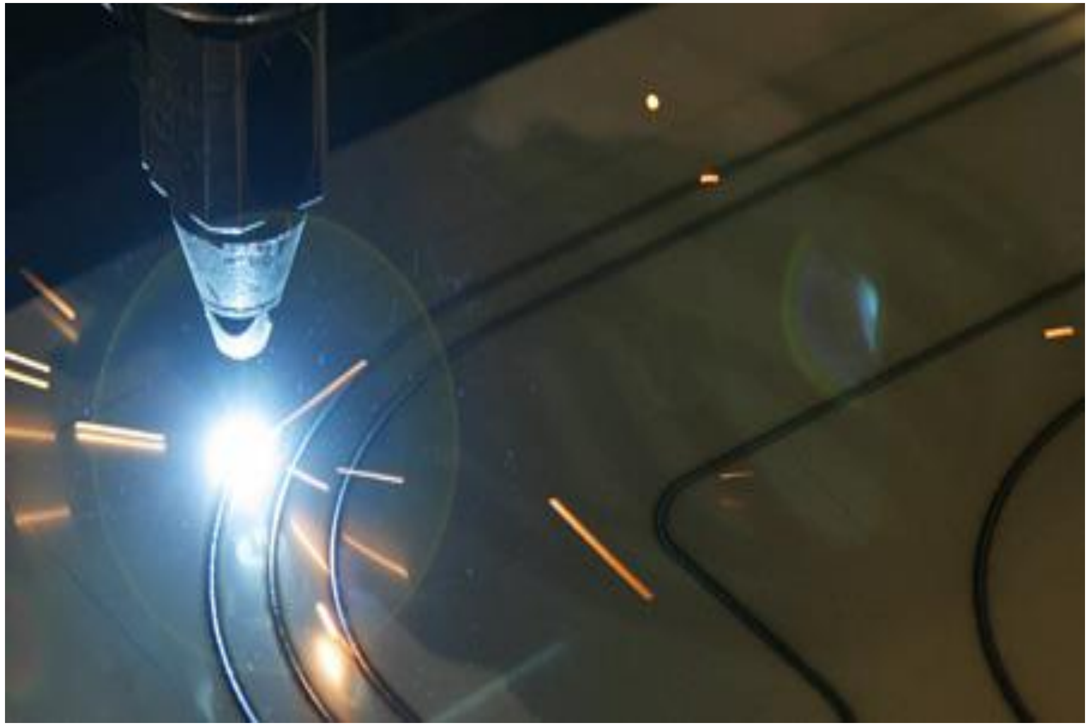


Image @ http://www.hightechfinland.com/uploads/image/high_speed_laser_welding.jpg on 15/06/2016 plasma-sprayed thermal barrier coatings were investigated by glazing with a high power laser in order to modify the structures. A study with focus on the microstructure of the laser-glazed TBCs is reported.

Experimental Procedure

- **Sample Preparation.**

Bond coatings:

Commercial available NiCrAlY metal powders (HHNiCrAlY-9, CAAMS, Beijing, China) with particle sizes ranging from 10 to 100 μm were air plasma-sprayed to make a coating with thickness of about 0.1 mm

Ceramic coatings:

Commercial 8wt.% Yttria partially stabilized zirconia (YPSZ) powders (HHYPSZ, CAAMS, Beijing, China) with particle sizes from 38.5 to 63 μm were air plasma-sprayed to make a coating with thickness of about 0.3 mm

Air plasma spray system (DH80, CAAMS, Beijing, China). The spraying parameters are listed in Table 1.

Table 1: The spraying parameters for the TBCs

	Current [A]	Voltage [V]	Primary gas Ar [$l\cdot min^{-1}$]	Primary gas N_2 [$l\cdot min^{-1}$]	Secondary gas H_2 [$l\cdot min^{-1}$]	Powder feeding rate [$g\cdot min^{-1}$]	Stand off distance [mm]
NiCrAlY	480	65	37	-	5	50	100
YPSZ	480	75	-	37	3-5	15	60

- **Laser-glazing.**

The Laser-glazing process was carried out on the plasma-sprayed TBC surface by using an industrial high power (maximum output power of 15 kW) CO_2 continuous wave laser (TLF15000, Trumph Lasercell, Germany) at a power of 3,500 W, as shown in figure 1. The laser system characteristics and processing parameters are listed in table 2.

Fig. 1 The industrial CO_2 continuous wave laser

Table 2 Laser system characteristics and processing parameters

Wave type:	Continuous
Wave length (μm)	10.6
Raw beam size (mm):	25
Focal length (mm):	357
Focal point diameter (mm):	0.7
Defocus distance (mm):	120
Glazing beam diameter (mm):	8.4
Power (W):	3,500
Scanning speed (mm/min):	10000

- **Microstructural Characterization.**

Surface morphologies and coating microstructure were observed by using a field emission scanning electron microscope (FESEM, Model FEI Sirion 200, USA). Fractured and polished cross sections of the laser-glazed ceramic coatings, which were perpendicular to the laser beam travel, were prepared to determine morphological and microstructural modifications along the coating thickness. The arithmetic mean roughnesses ($R\alpha$) of the ceramic coating surfaces with and without laser-glazing were determined by a mechanical profilometer (TR100, Time Inc., Beijing, China) performed along two orthogonal directions on the coating surfaces.

Results and Discussion

Microstructural Analyses

a) b)

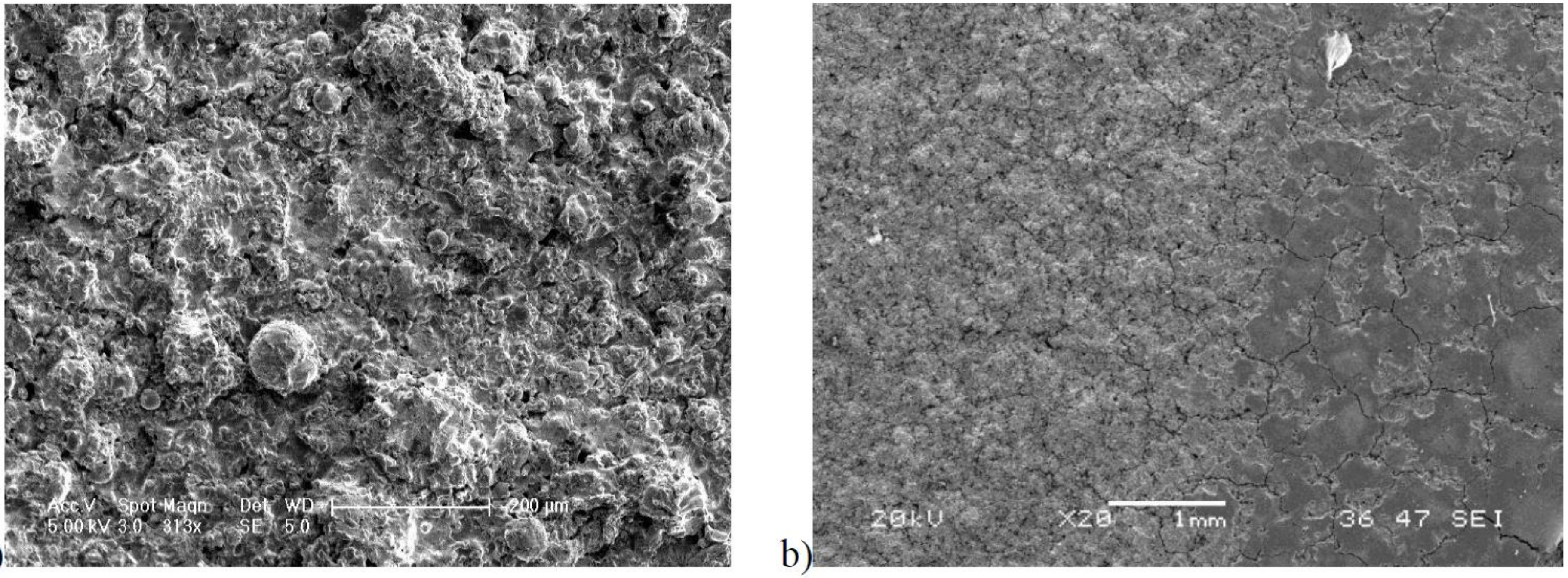


Fig. 2 SEM images of a) the top surface of the as-sprayed ceramic coating and b) the contrast of surface morphology in a region containing both laser treated (right) and untreated (left) areas.

a) b)

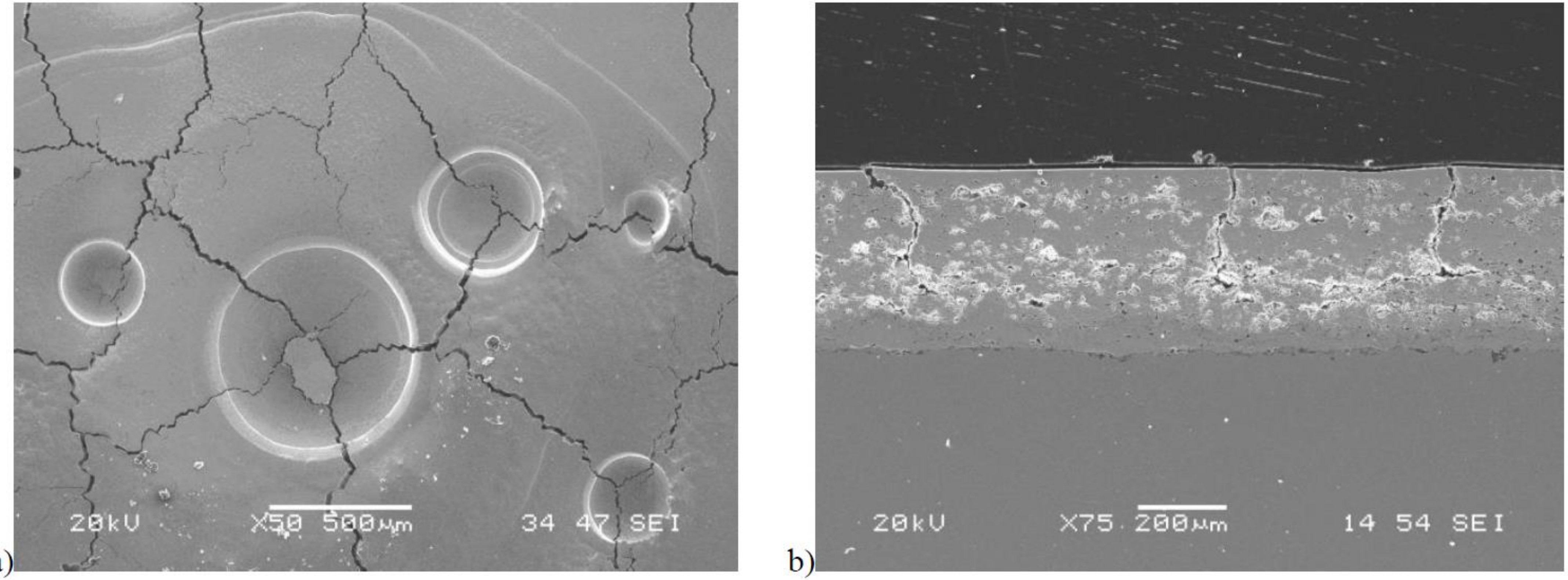
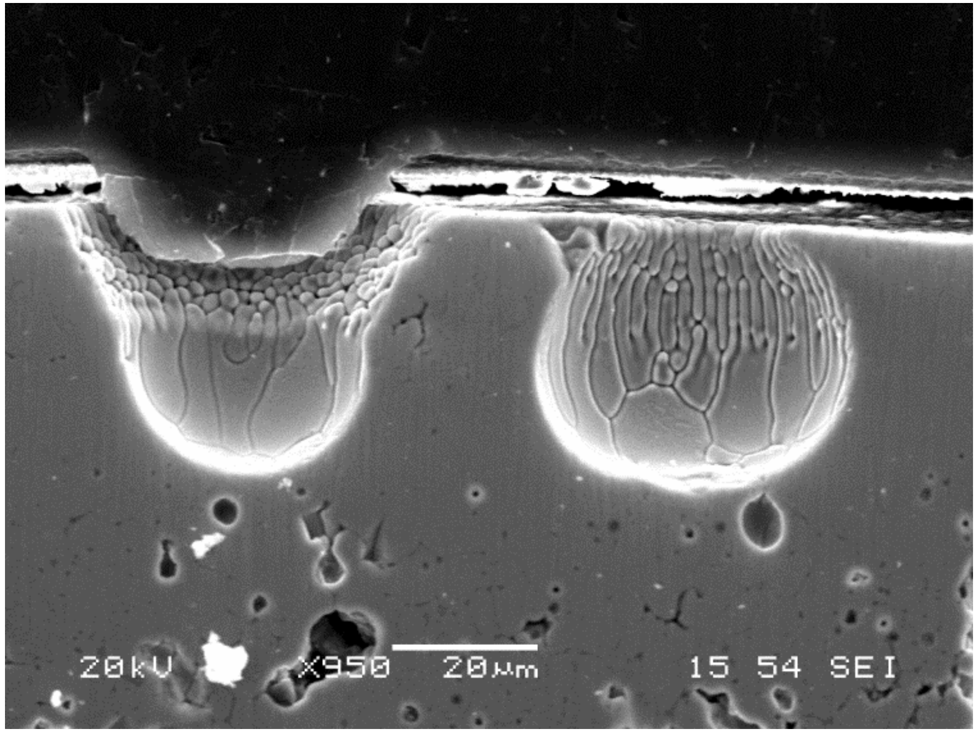
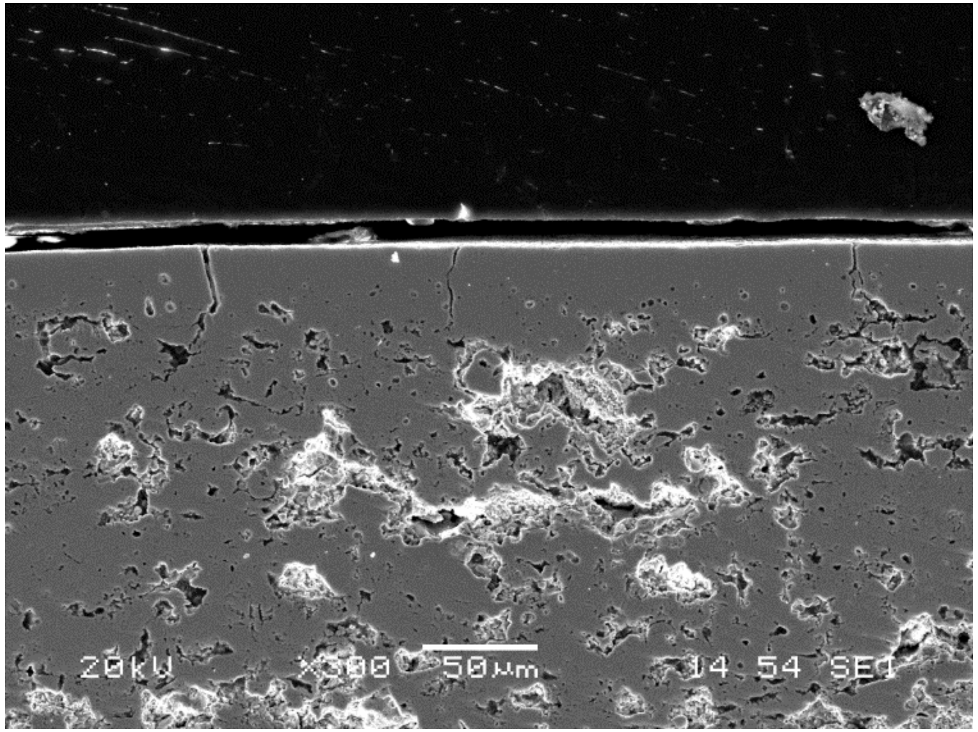


Fig. 3 a)The surface morphology and b) polished cross section of the laser-glazed TBCs





Figures to show the craters and microcracks in the cross sections

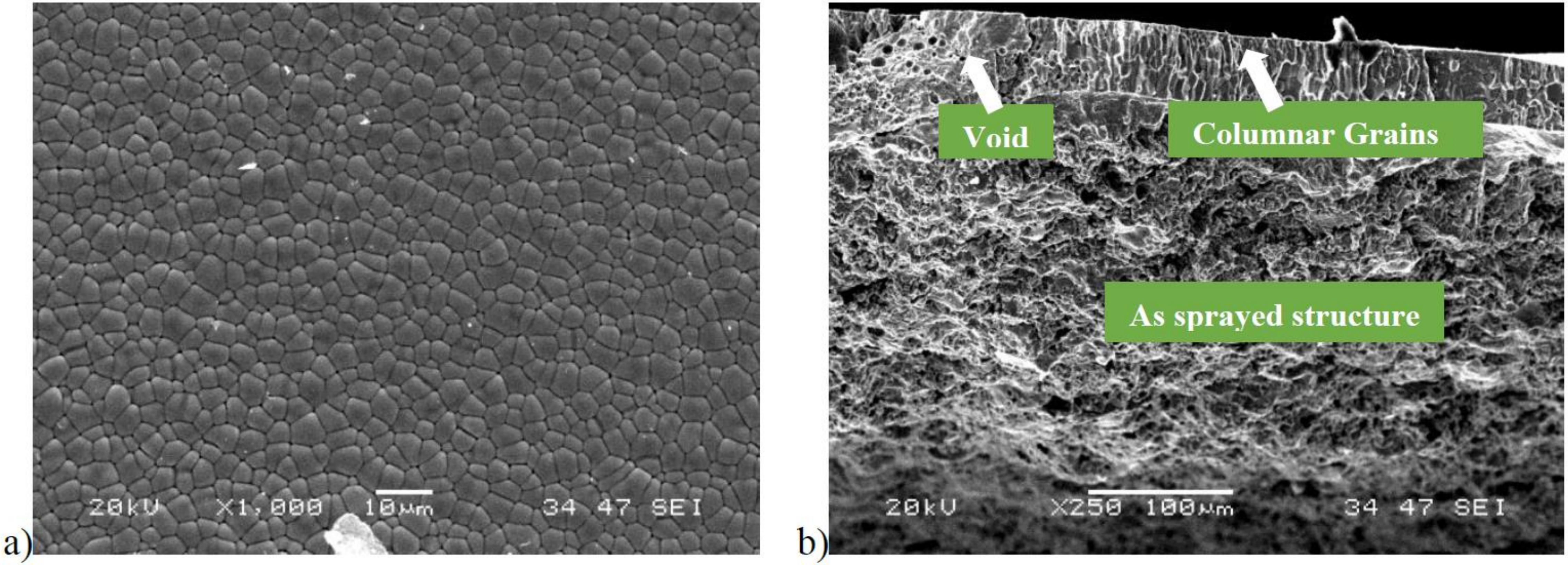
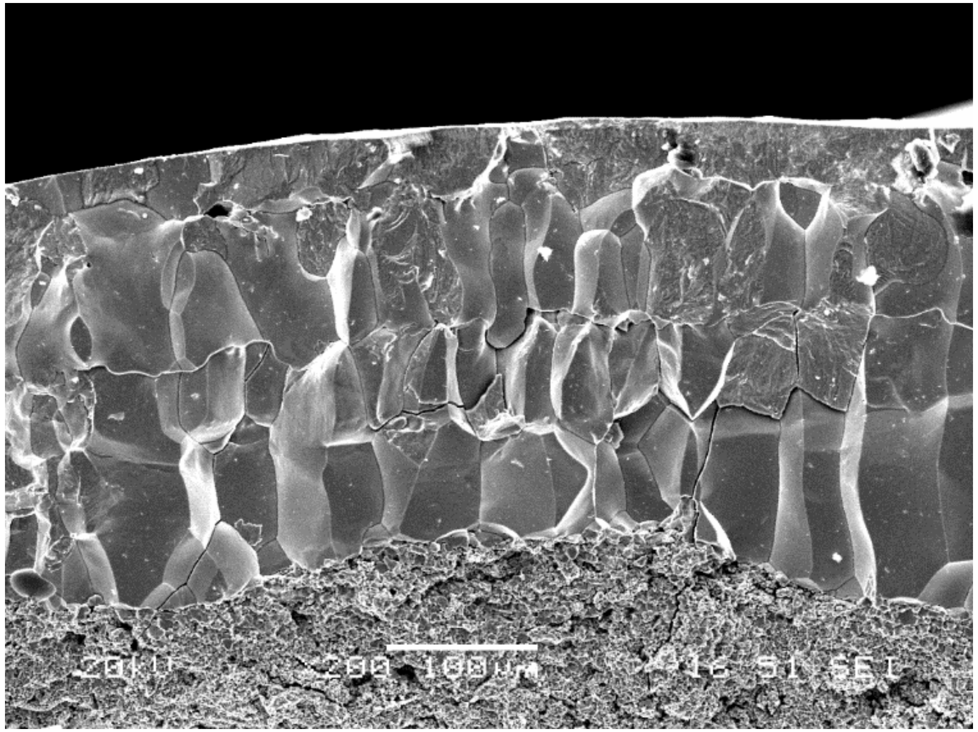
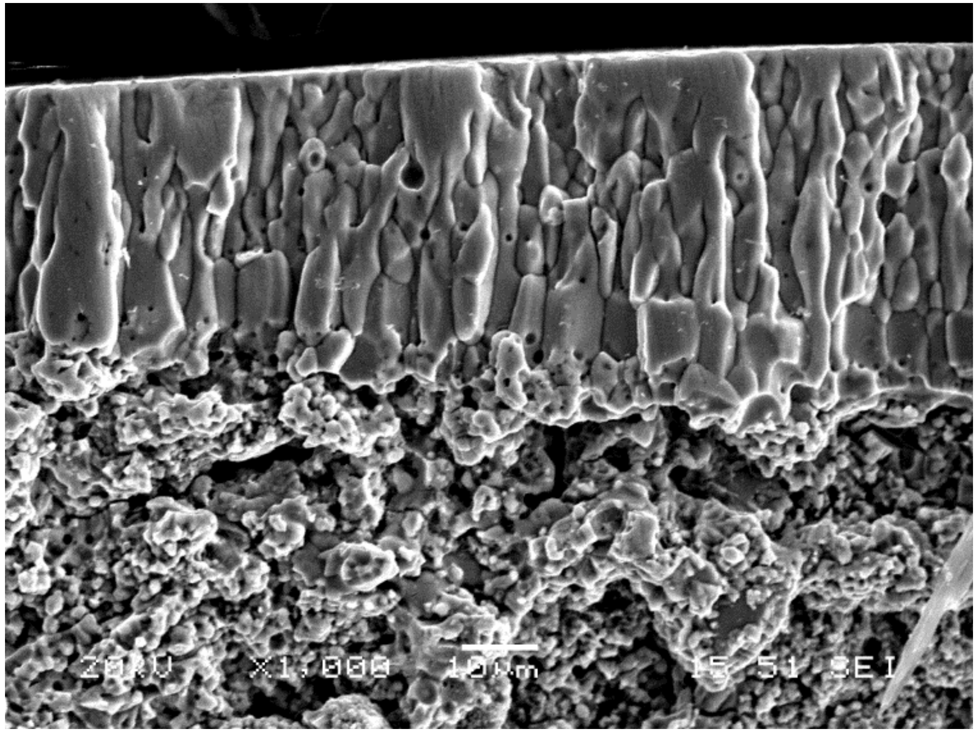


Fig. 4 SEM images of a) the top surface and b) the fractured cross-section of the laser-glazed coatings





Figures to show the fractured cross sections

Surface Roughness

Surface roughness (R_α) has been measured for both specimens. The surface roughness for as-sprayed coating is 9.3±0.8 μm, while that for the laser-glazed coating is reduced to 5.1±0.4 μm, as illustrated in Fig. 5. The result indicates an obvious reduction on surface roughness values after laser processing in spite of the forming of craters and microcrack networks on the surface, and thus generates a smoother surface.

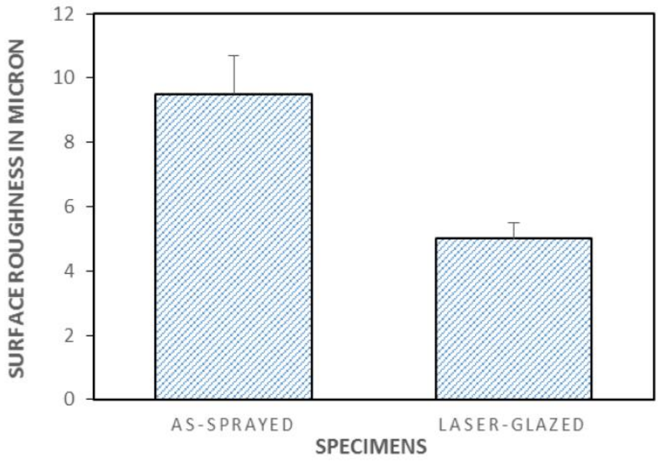


Fig. 5 Comparison of the surface roughness values (R_α) between the as-sprayed and the laser-glazed ceramic coatings

Conclusion

Plasma-sprayed TBCs have been subjected to laser-glazing processes which provide a remelting and subsequent solidification of the surface.

- Laser-glazing carried out on TBCs has resulted in a smooth and dense glazed surface with craters and a network of microcracks.
- The laser-glazed region consists of a columnar microstructure. T
- here are segmentation microcracks in the laser-glazed coatings, which don’t run through the coatings along thickness.
- An obvious reduction on surface roughness is achieved after laser processing.

Thanks for your attention