Investigation of Characterization on Nano-Structured Thermal Barrier Coatings for Aerospace Applications

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OUTLINE

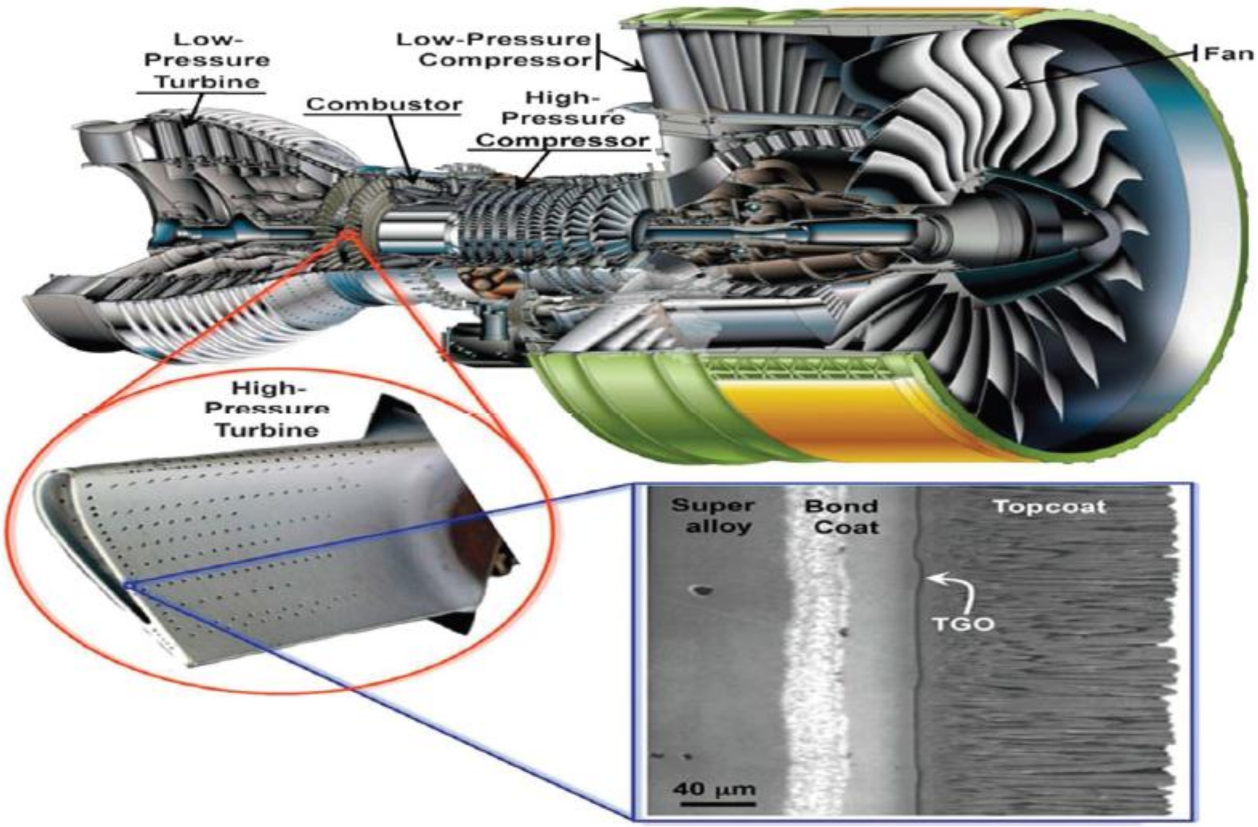
- Introduction
- TBC failures
- Motivation and objectives
- Preparation of Nano powder
- Testing of TBC failure
- Summary
- Acknowledgement
- Reference

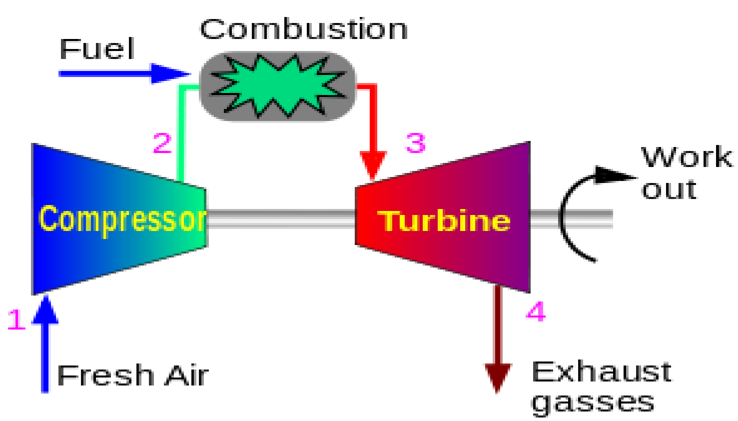
INTRODUCTION

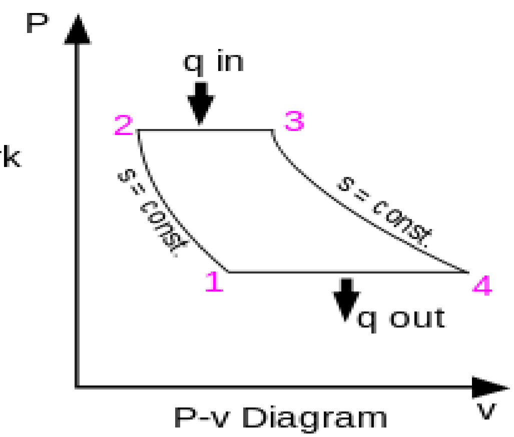
- TBCs have been widely used in hot-section metal components in gas turbines either to increase the inlet temperature with a consequent improvement of the efficiency or to reduce the requirements of the cooling air.
- Hence, in this investigation was made to synthesise, spheroidize and spray deposit LZ material
- thermal plasma as a major materials processing technique and Suitable characterization techniques have been used to study the material modifications
- Composite Layer means mixed LZ and YSZ powders with selected volume ratios allow to combine advantages of LZ thermal insulating performance and YSZ thermal durability also reviewed.
- future research directions of lanthanum Zirconate for next-generation TBC applications in gas turbines are proposed.

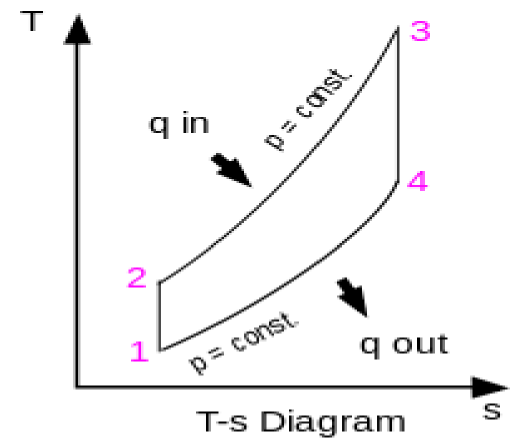
AIRCRAFT GAS TURBINE ENGINE PROTECTED BY TBCS

- As we know that increase in turbine inlet temperature results in increased thermal efficiency
- reduce the requirements of the cooling air.
- TBC can be applied on both Turbine blades and combustion chambers.



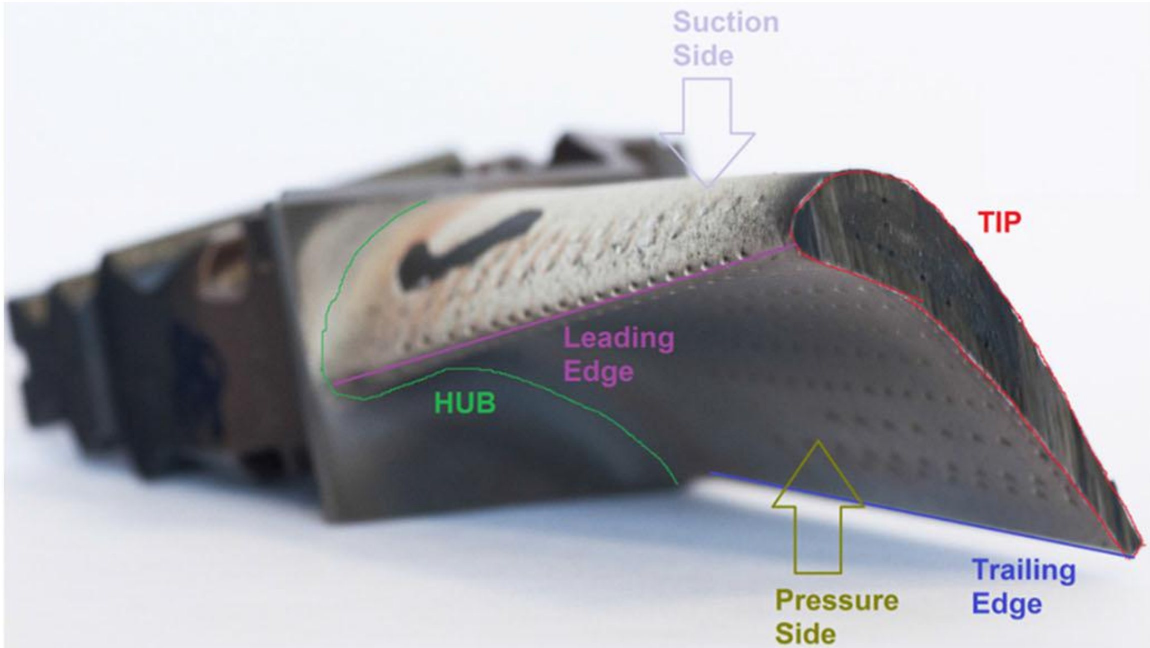






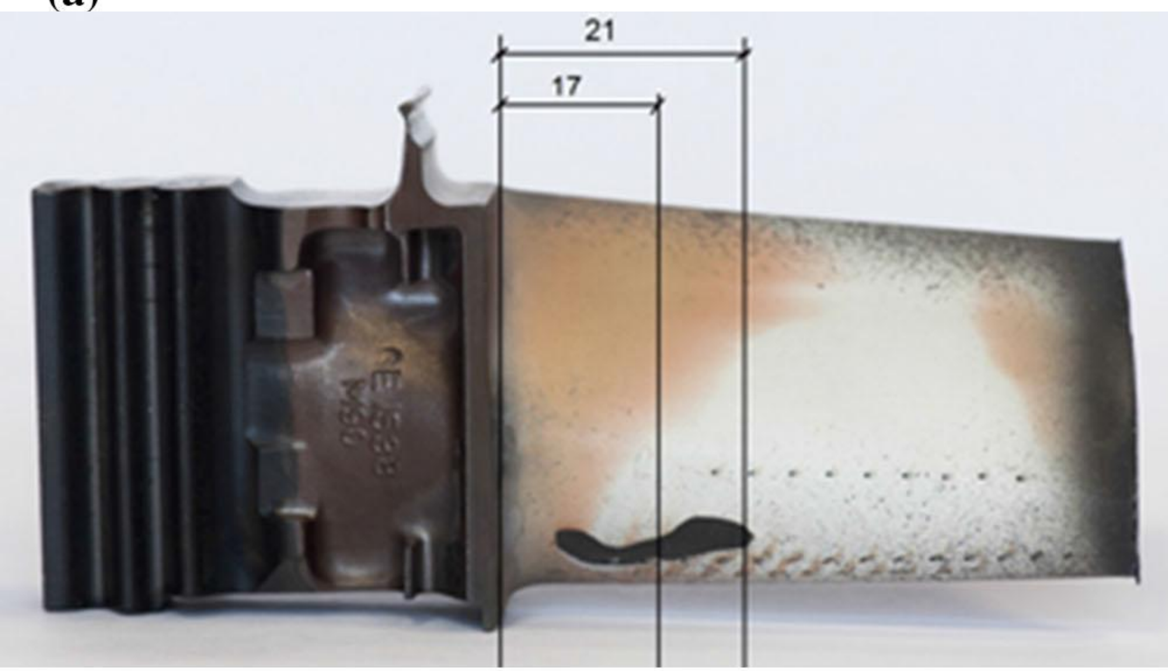
TBC FAILURES

COATING DECOHESION FAILURE



(a)

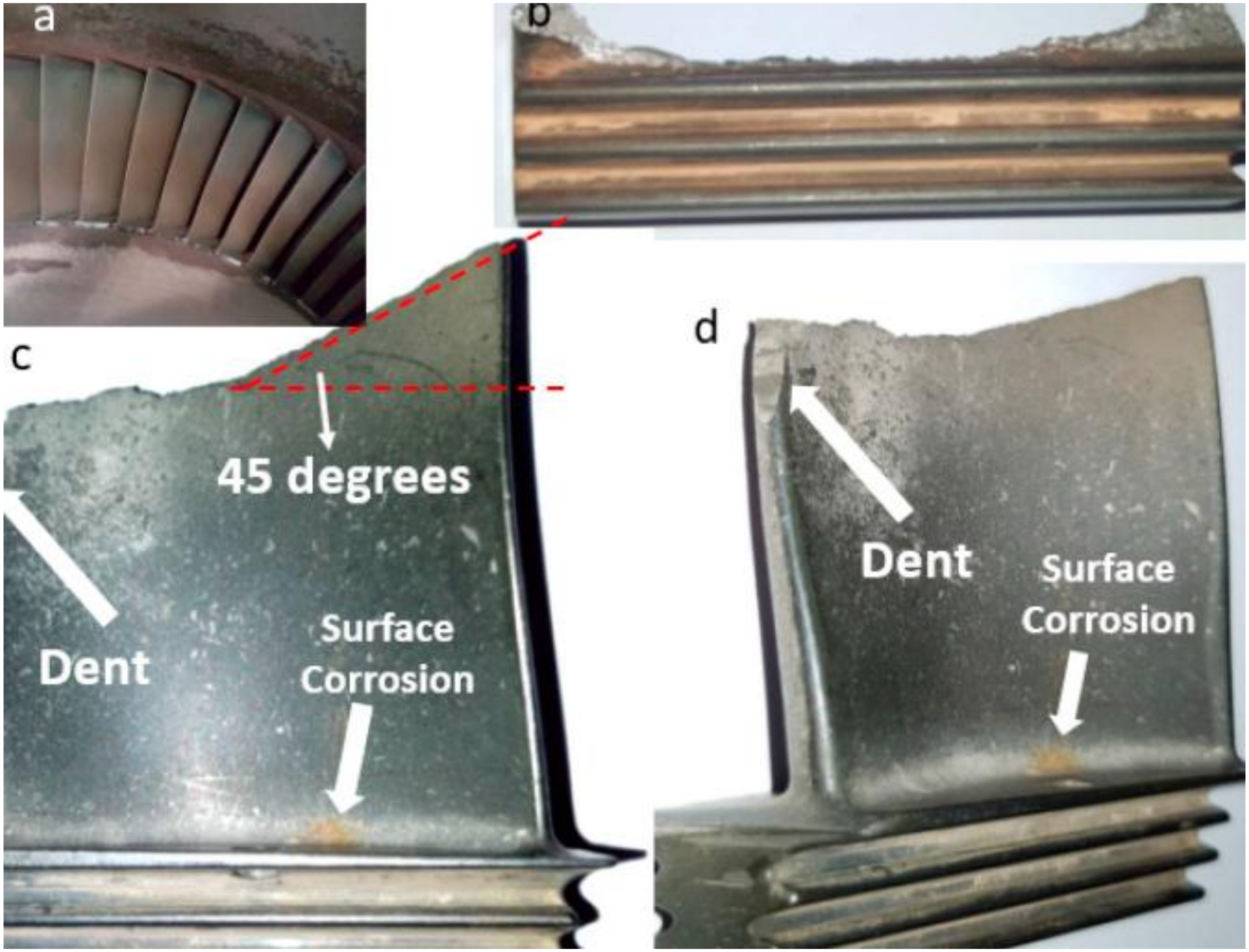
(b)



(a)

(b)

TBC FAILURES
VISUAL OBSERVATION OF BROKEN BLADE



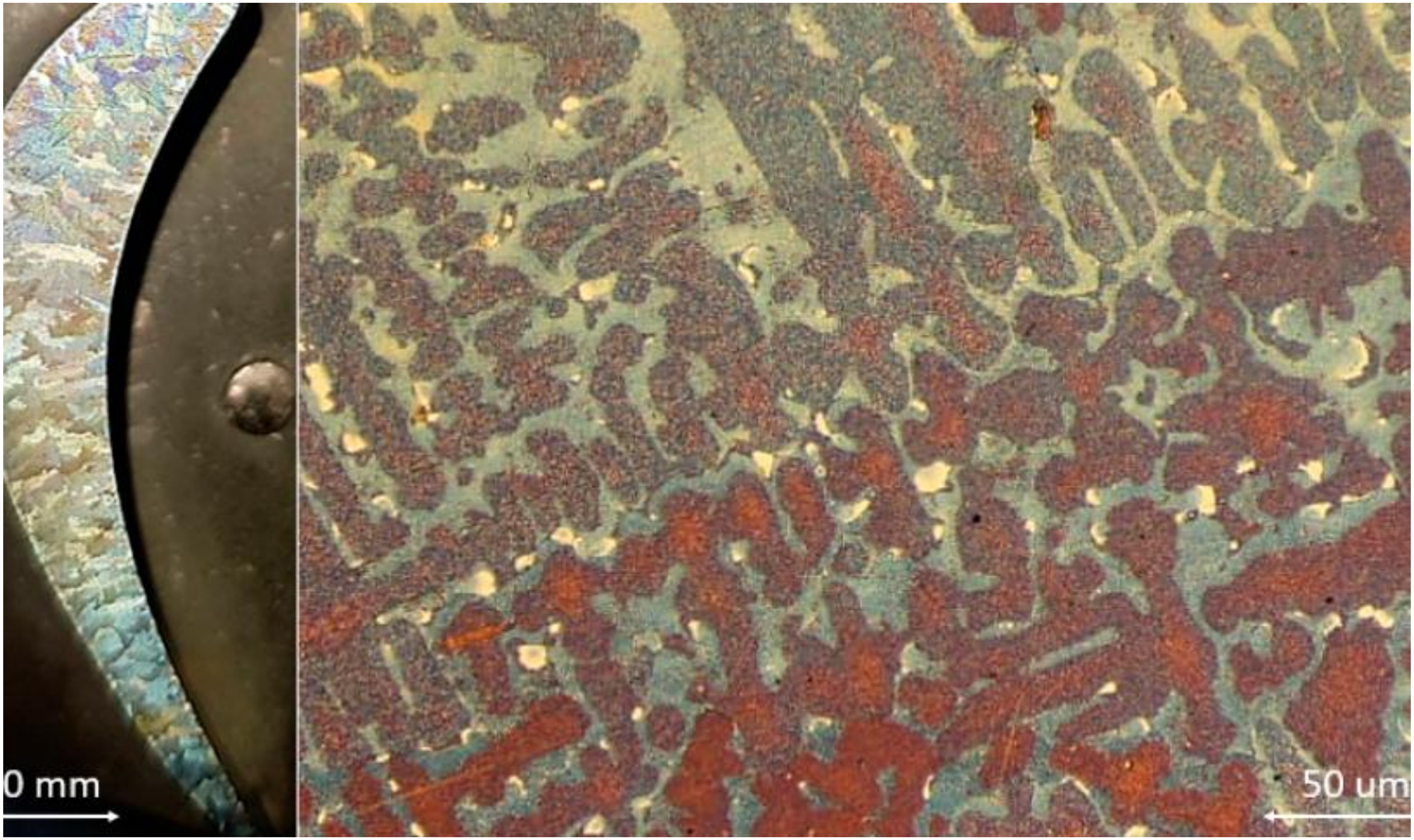
(a) blades in the assembled condition

(b) failed blade from the root

(c,d) broken blade from the airfoil

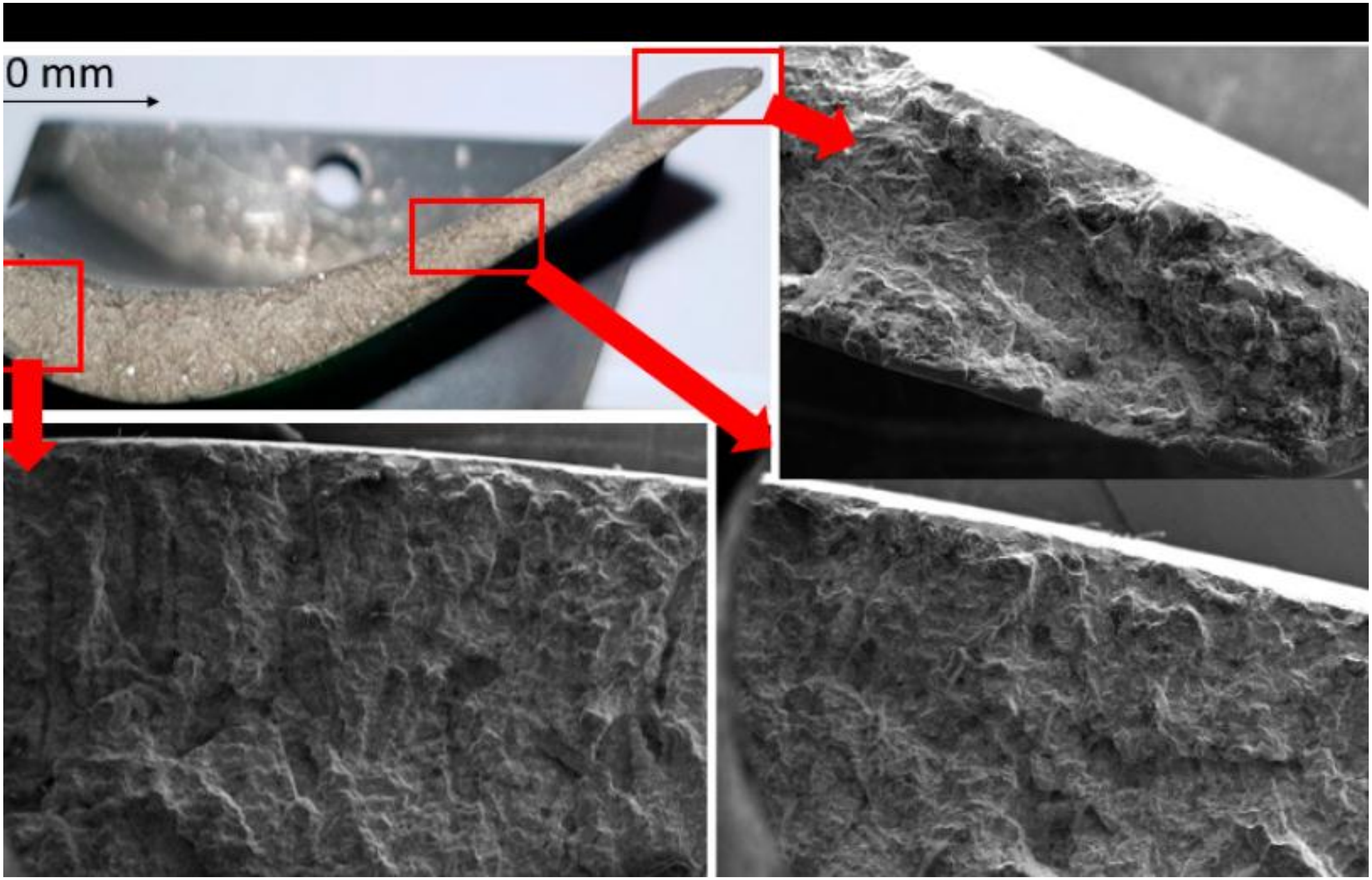
TBC FAILURES

Macro and optical microscope images of failed blades



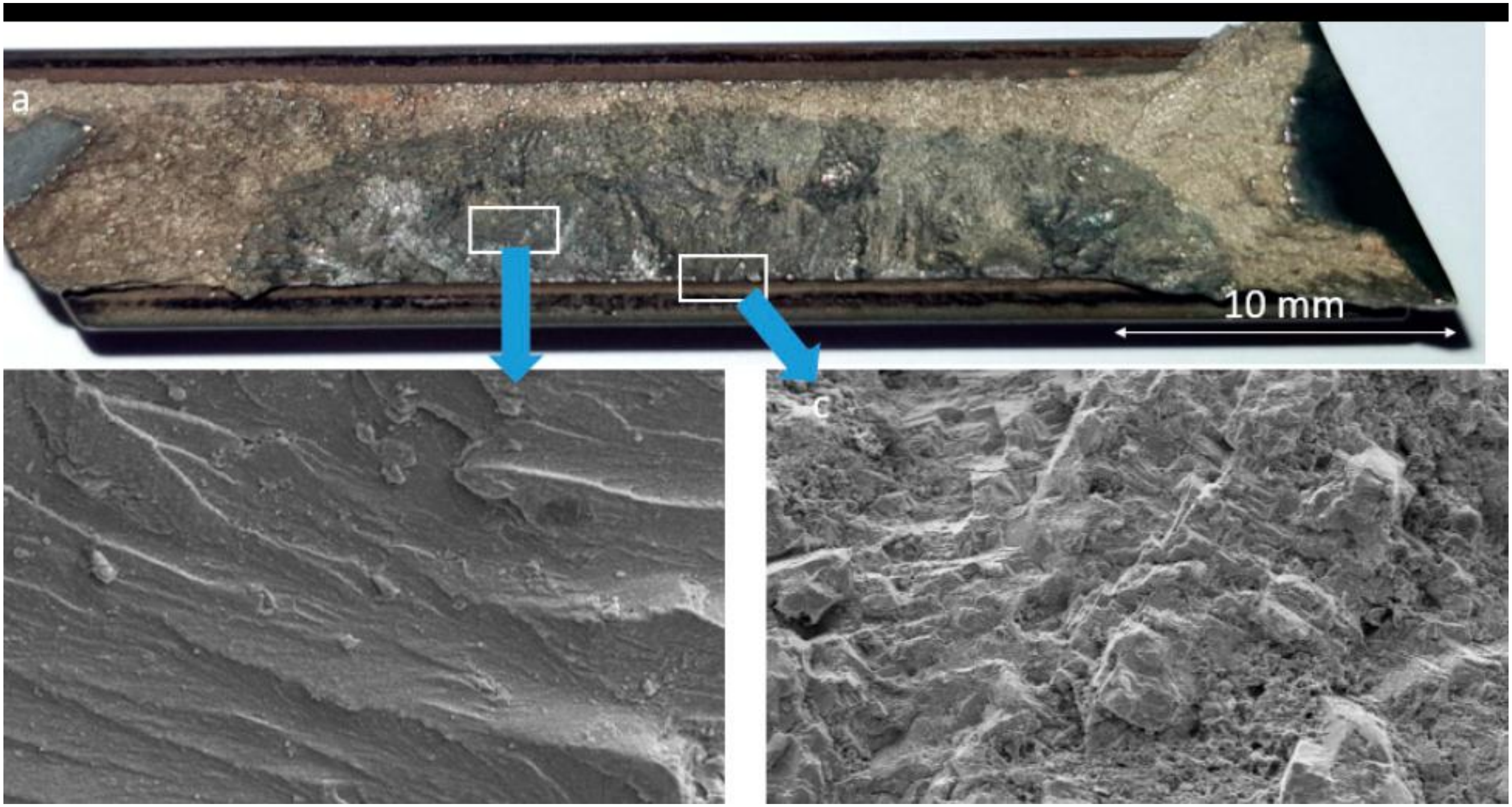
TBC FAILURES

Fracture Surface of the Blade, Broken From The Airfoil

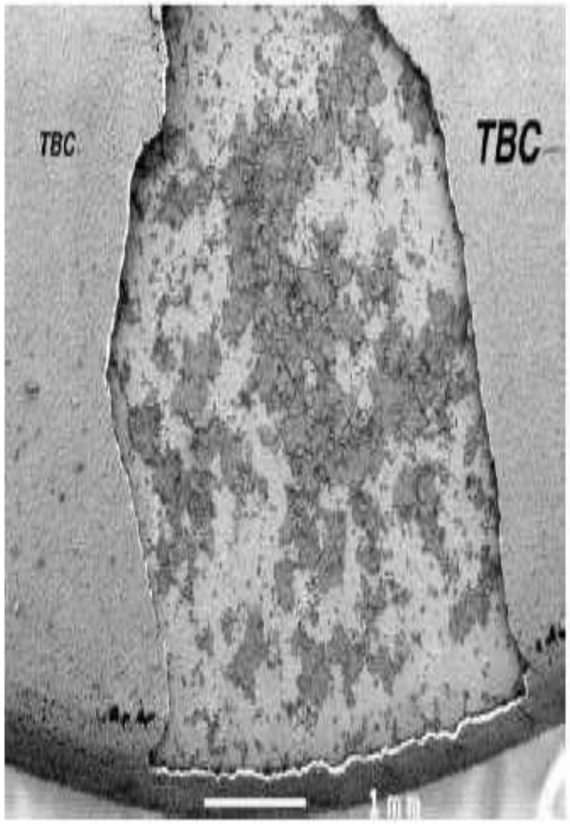


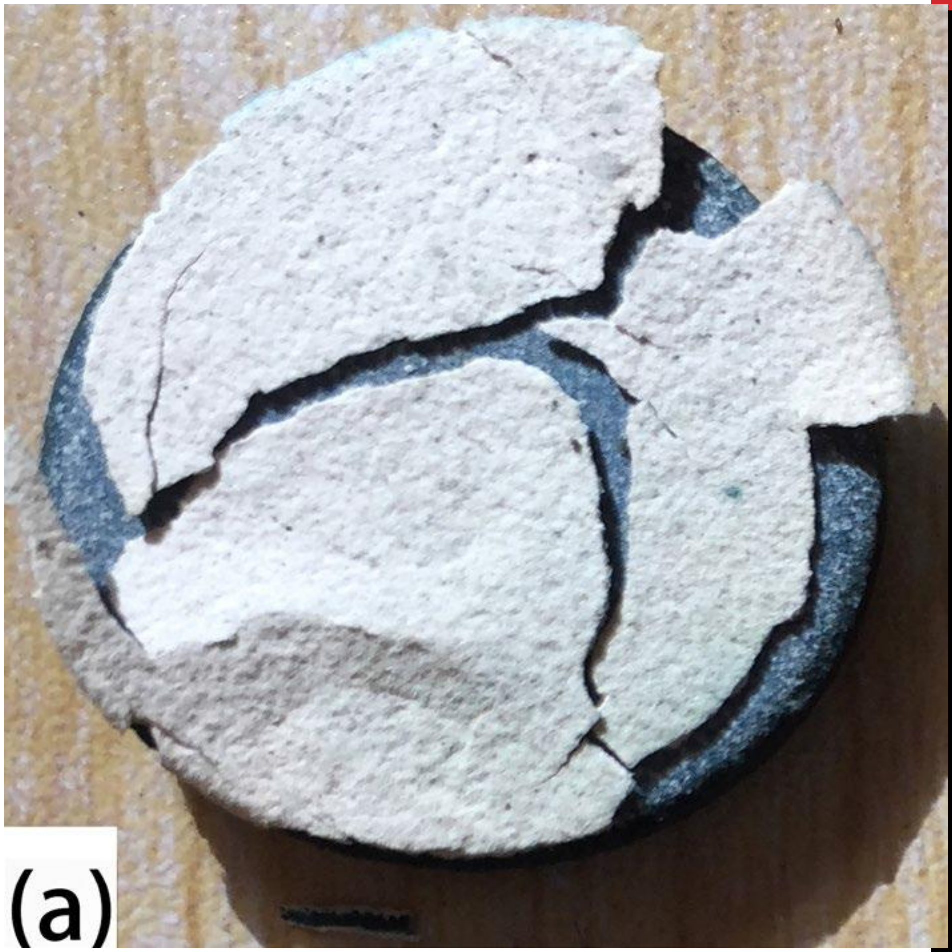
TBC FAILURES

fracture surface of the blade, failed from the root



TBC FAILURES
(THERMAL CYCLING TEST)





ADVANTAGES OF YTTRIA STABILIZED ZIRCONIA

- Zirconia partially stabilized with 7 wt% yttria (7YSZ) is the current state-of-the-art thermal barrier coating material.
- High Melting Point (oC)

- Coefficient of Thermal Expansion (x10-6/K) (@1000 oC)

LIMITATION OF YTTRIA STABILIZED ZIRCONIA

- Zirconia partially stabilized with 7 wt% yttria (7YSZ) is the current state-of-the-art thermal barrier coating material.
- However, at temperatures higher than 1200 ^{o}C, YSZ layers are prone to **sintering**, which increases thermal conductivity and makes them less effective.
- Phase changed above 1200 ^{o}C.
- The sintered and densified coatings can also **reduce thermal stress and strain tolerance**, which can reduce the coating's durability significantly.

MOTIVATION AND OBJECTIVE

- To further increase the operating temperature of turbine engines, alternative TBC materials with lower thermal conductivity, higher operating temperatures and better sintering resistance are required.
- The objective of the project is to develop a novel nano structured YSZ and lanthanum zirconate based multi-layer thermal barrier coating system.
- investigation was carried out to synthesise, spheroidize and spray deposit YSZ using the thermal plasma process.
- The ultimate goal is to develop pyrochlore oxide based coating with improved high-temperature properties.

YSZ PROPERTY

Materials property	8YSZ
Melting Point (^oC)	2680
Maximum Operating Temperature (^oC)	1200
Thermal Conductivity (W/m-K) (@ 800^oC)	2.12
Coefficient of Thermal Expansion (x10^{-6}/K) (@1000 ^oC)	11.0
Density (g/cm^3)	6.07
Specific heat (J/g-K) (@1000 ^oC)	0.64

PREPARATION OF YSZ

- The commercial 8YSZ) were used as starting materials.
- The 8YSZfeedstocks were fabricated by the nanopowder granulation method, i.e., ball milling,spray drying, sintering and plasma treatment.
- The 8YSZ nanopowder was first uniformly dispersed in deionized water and polyvinyl alcohol aqueous solution to form slurry under 24 h ball-milling. Subsequently, spray drying was carried out for granulation.
- After that, the spray dried powders were sintered at 1200 °C to enhance densification. Finally, the plasma treatment was necessary for spheroidization and further densification.

PREPARATION OF YSZ

Manufacturing criteria of feedstock powders

(1)spherical shape powder,

(2)uniform and fine particle size,

(3) homogeneous composition,

(4) high purity, and

(5) low fabrication cost.

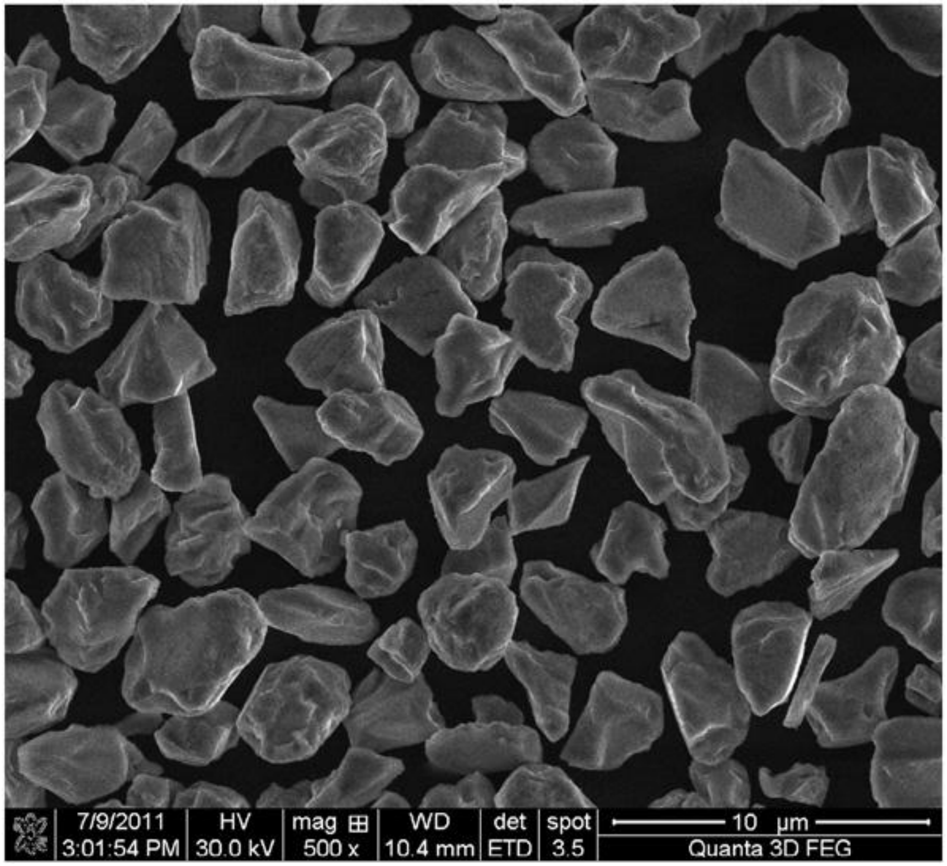
PREPARATION

Solid state reaction Method

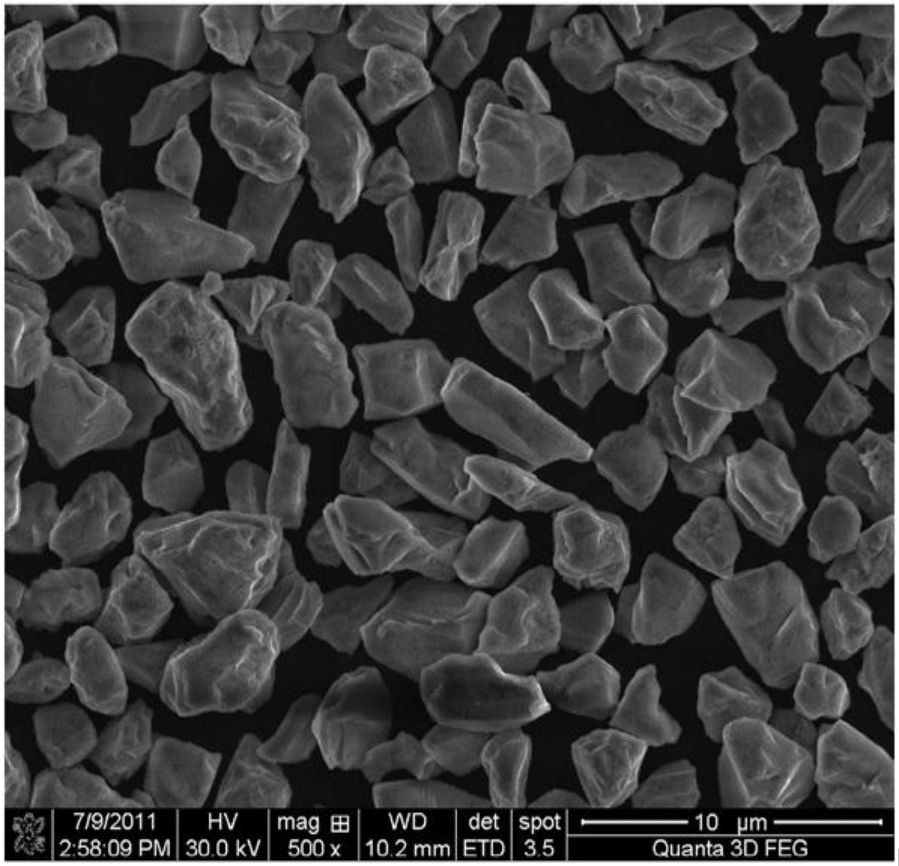
Binder: **polyvinyl pyrollidone**

Ball mill- **Medium- water and zirconia balls as the mixing medium.**

Cold press- **Tubular furnace**

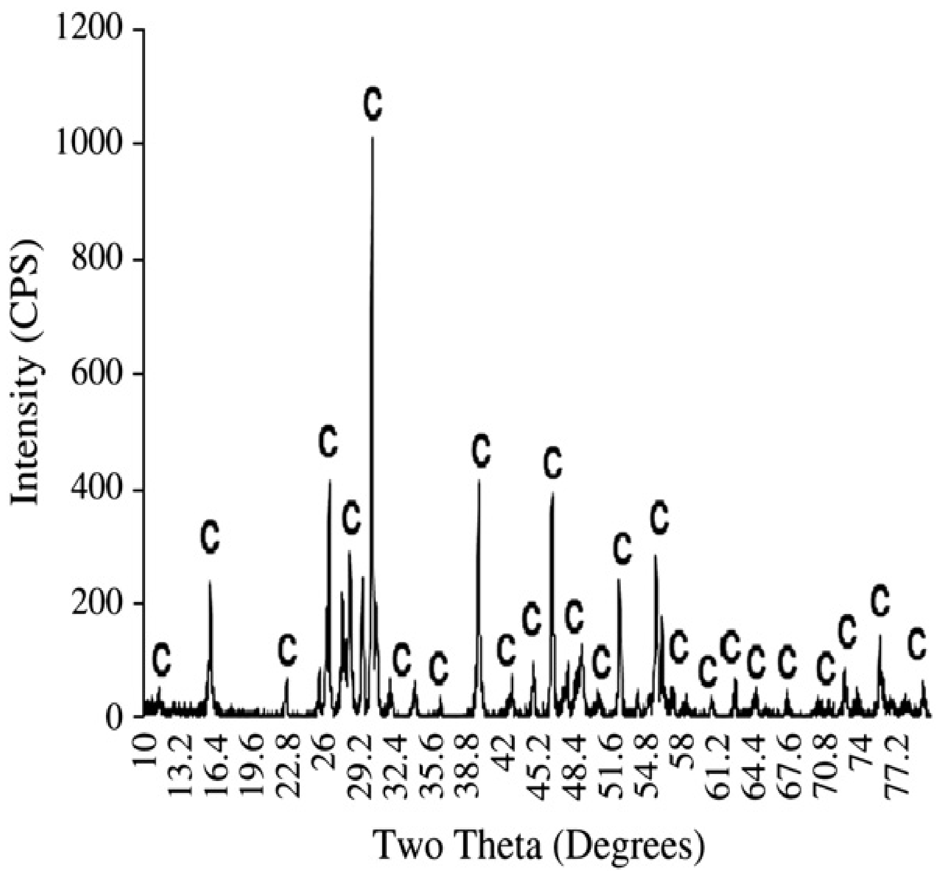


zirconium oxide powder.

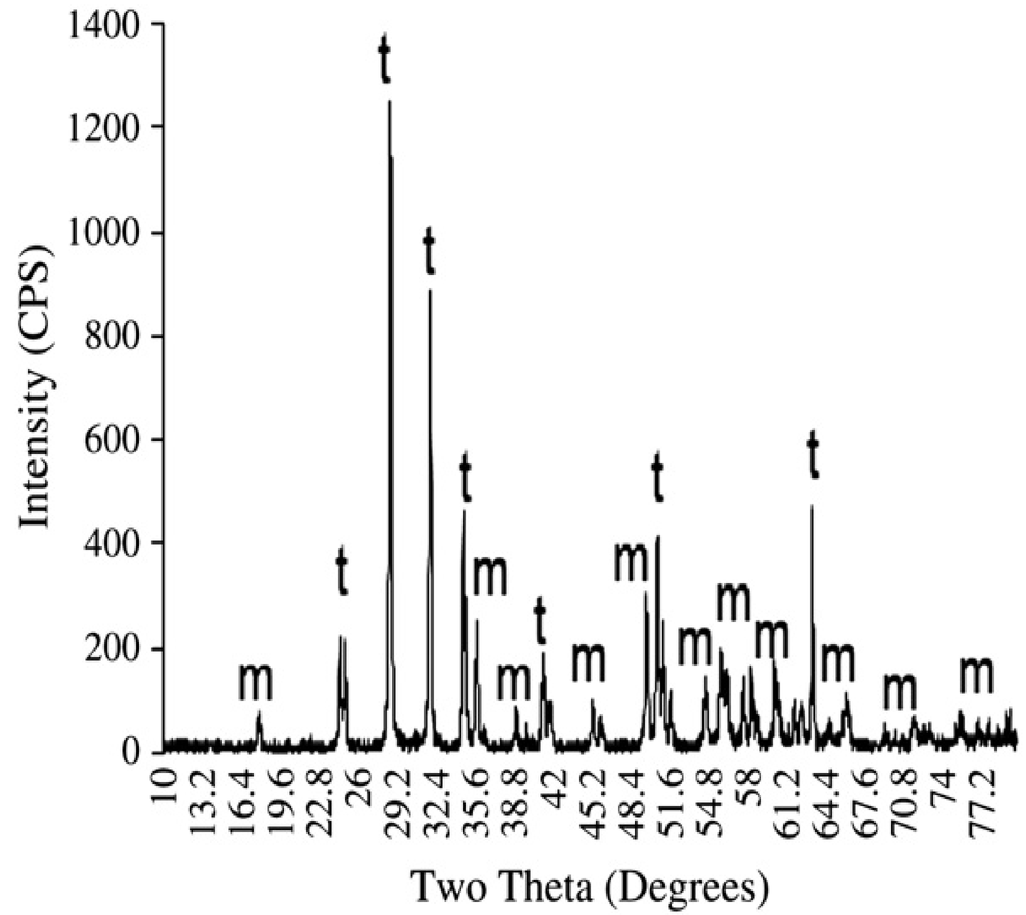


lanthanum oxide powder

PREPARATION

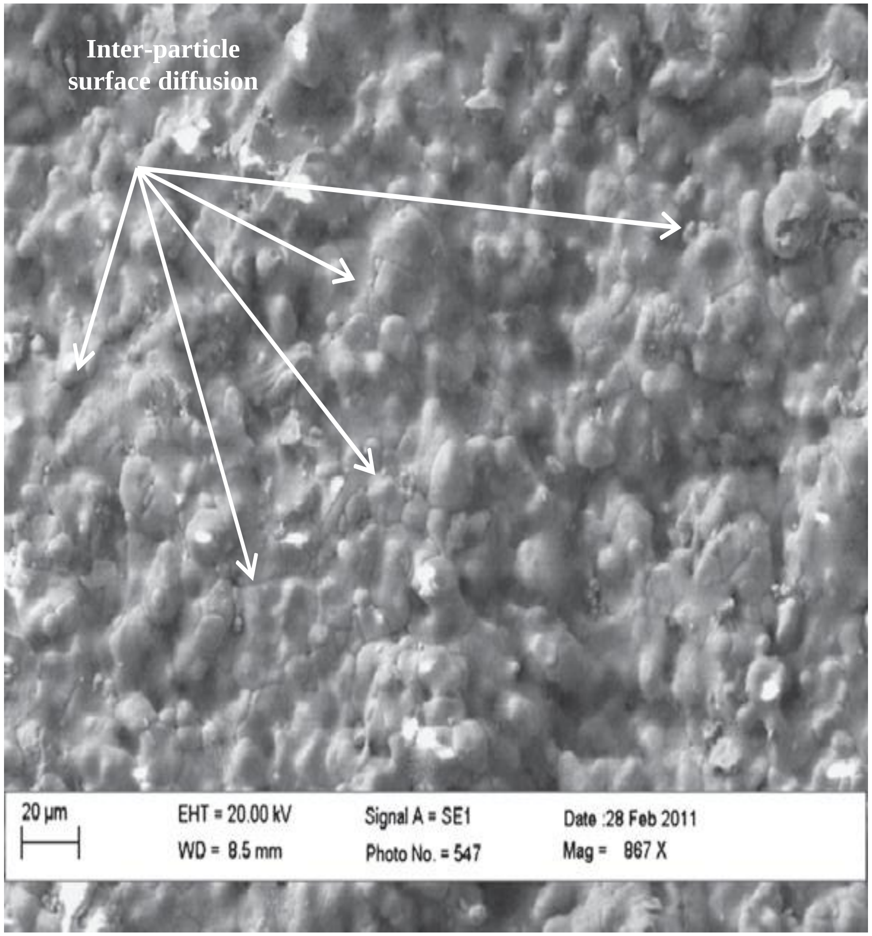


lanthanum oxide powder

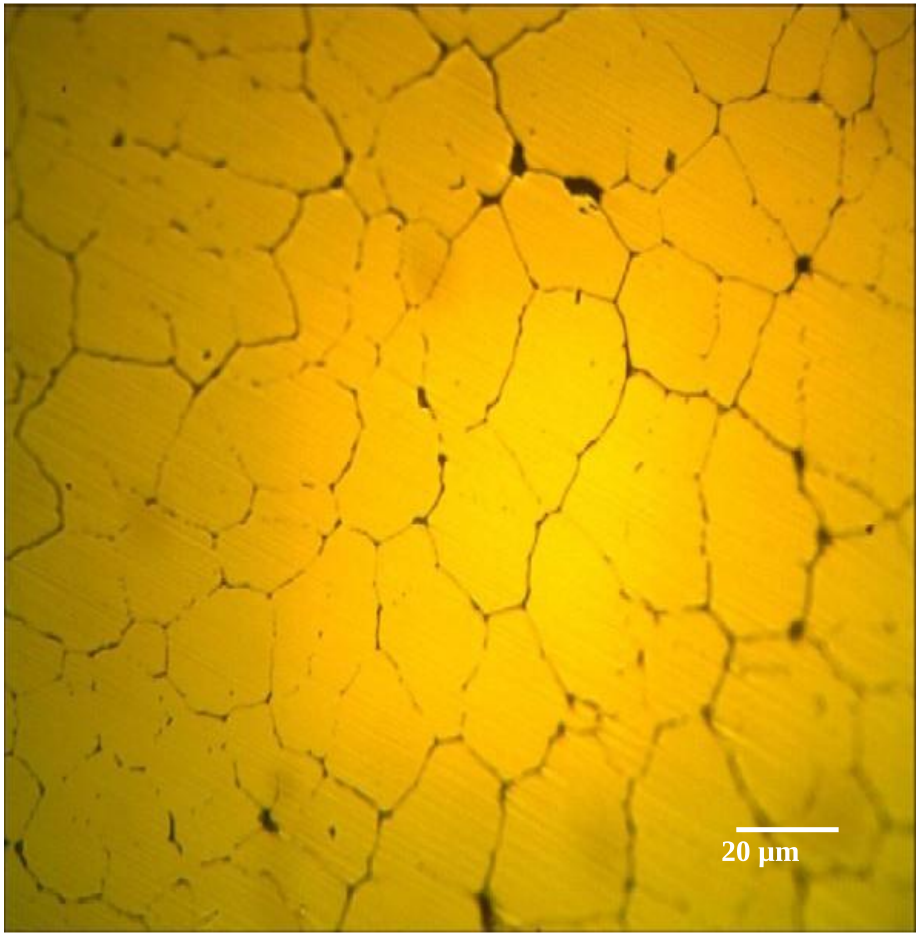


zirconium oxide powder.

PREPARATION



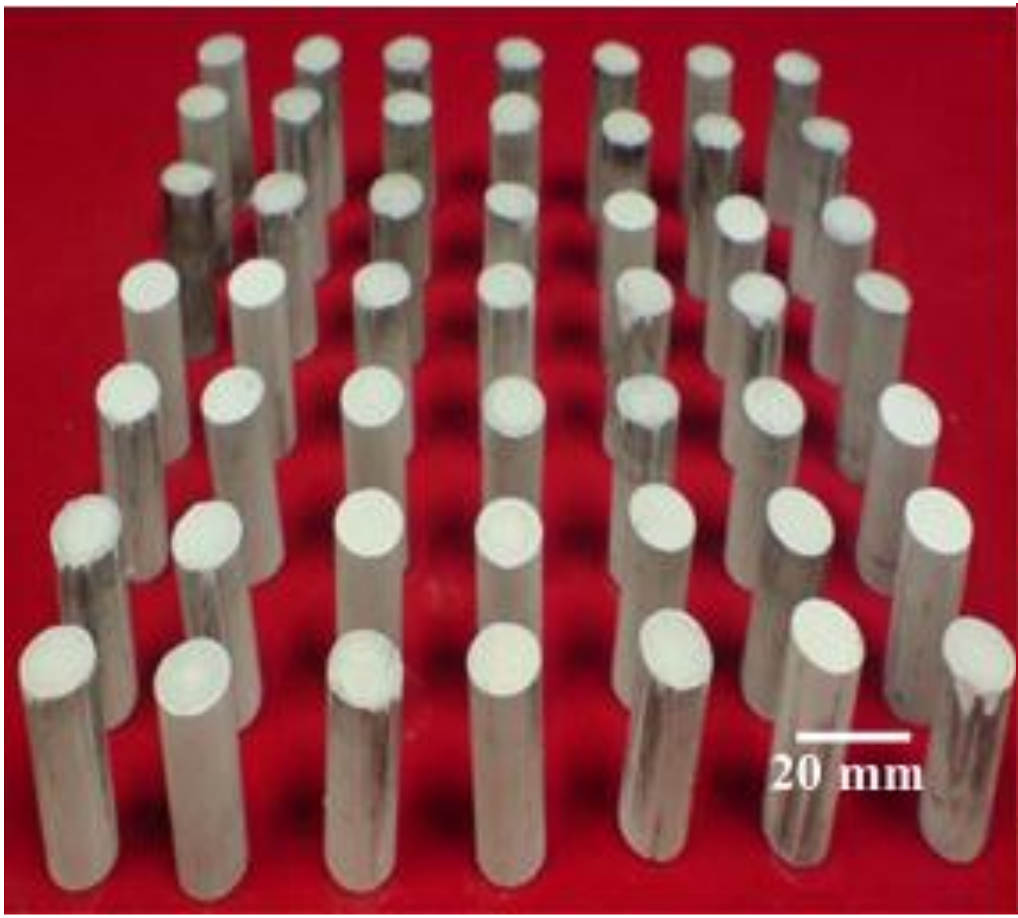
Top surface of sintered pellet. @ 1700 C for 10hours



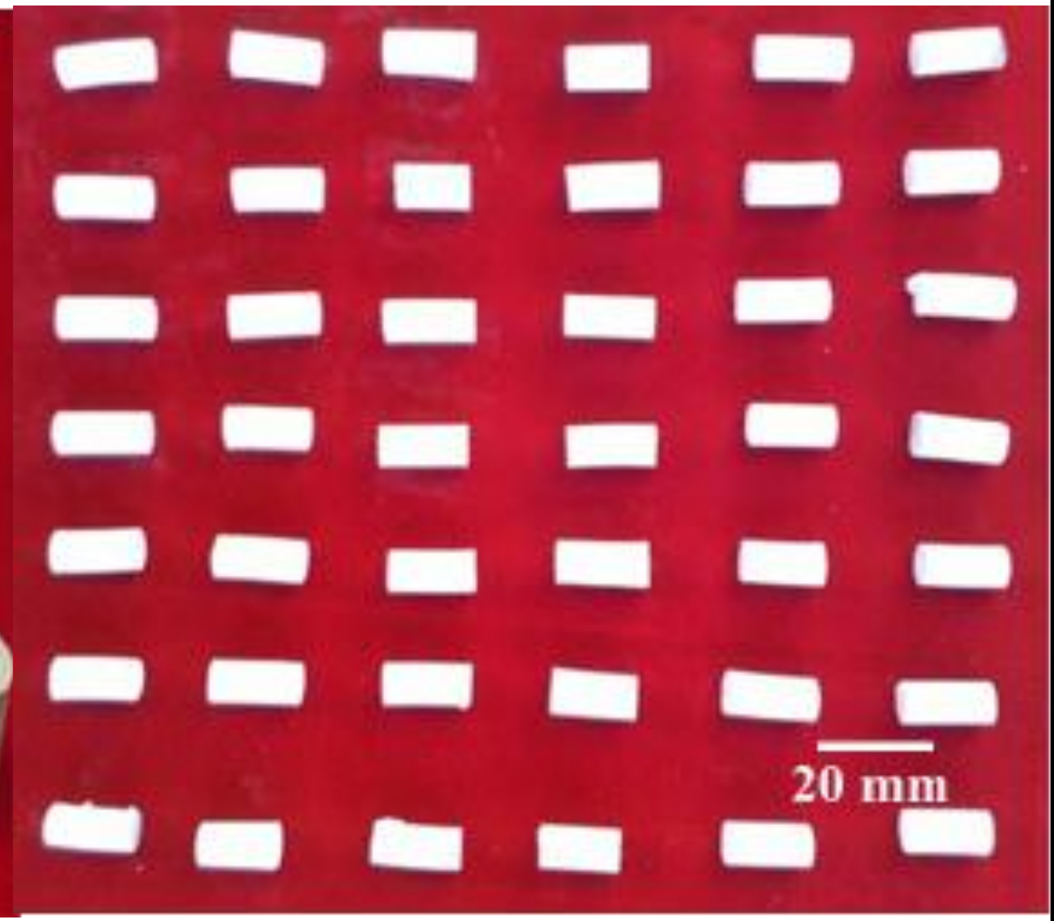
Grain evolution in sintered pellet

PREPARATION OF LZ

- Transferred Arc Plasma (TAP) melting
- Plasma spheroidization
- Plasma spray deposition



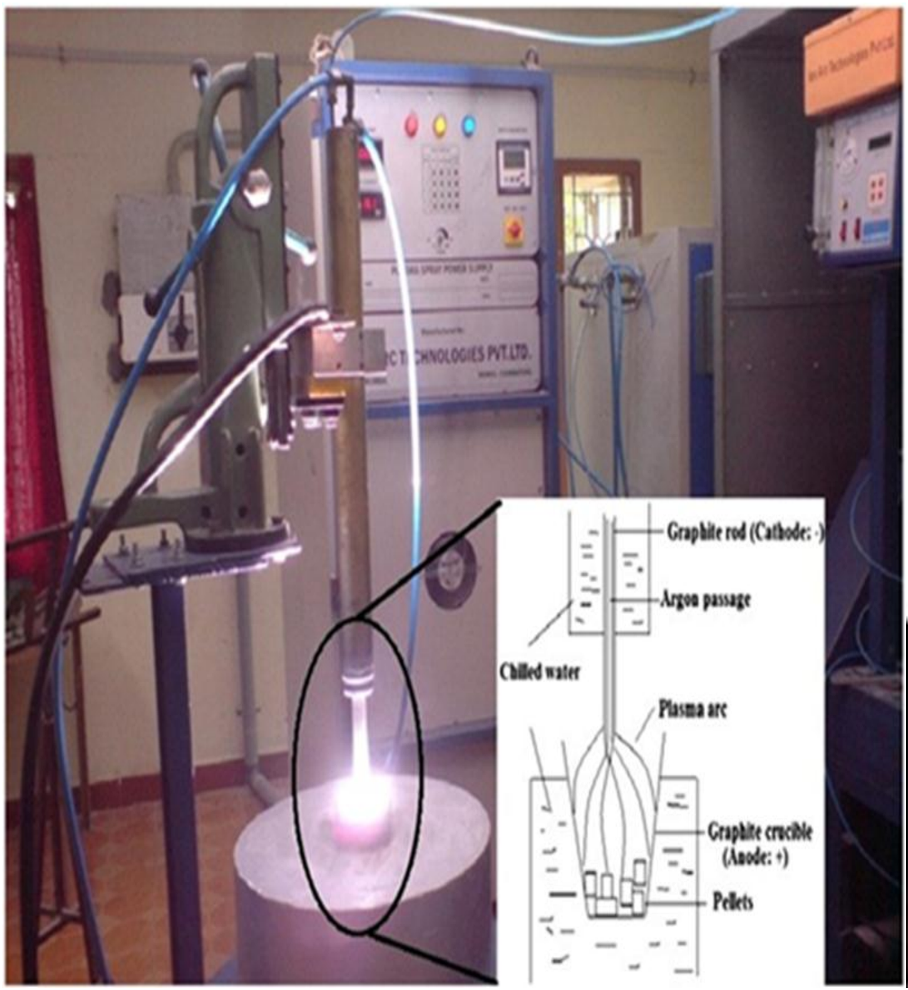
Stoichiometrically varied, mixed and cold pressed pellets.

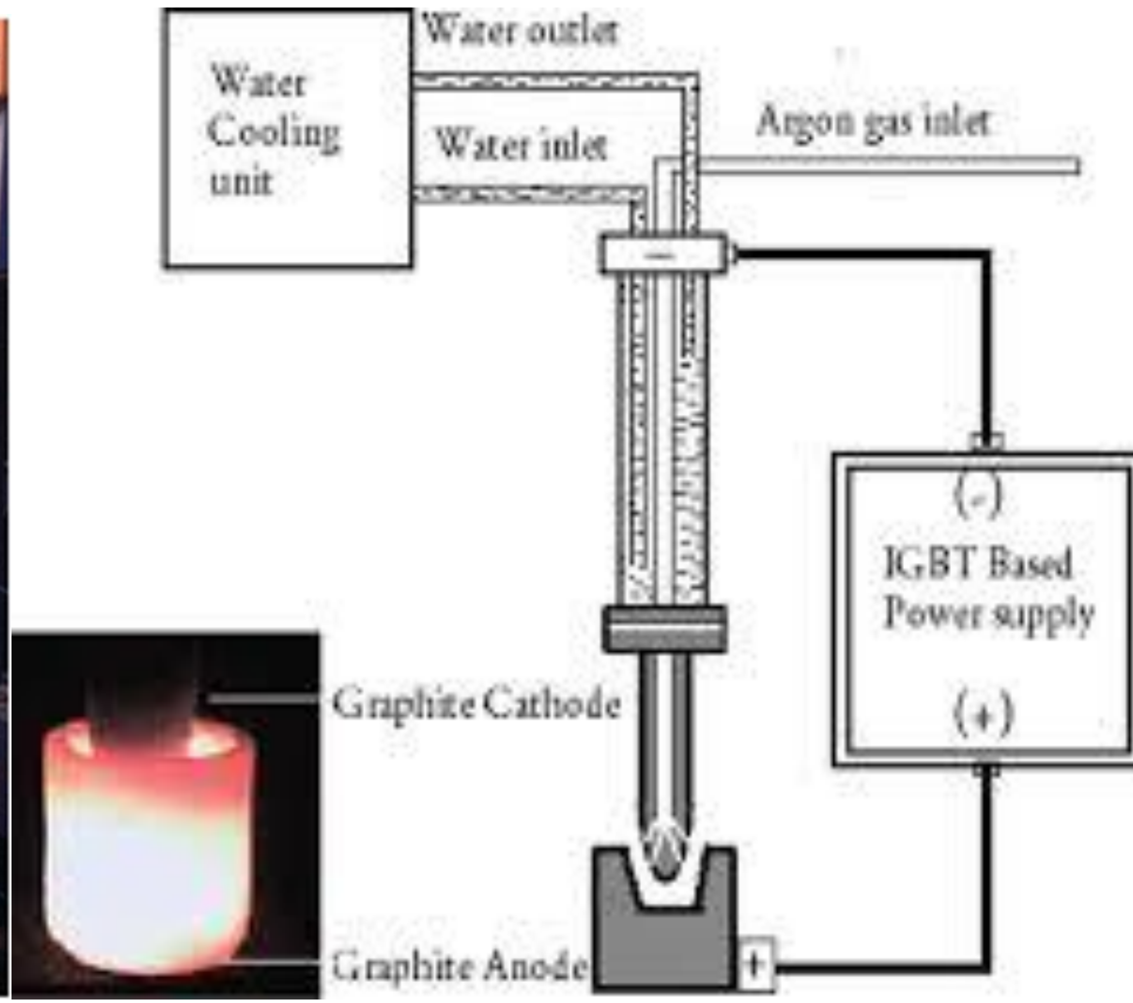


Pellets after sintering at 1700 °C for 10 hours.

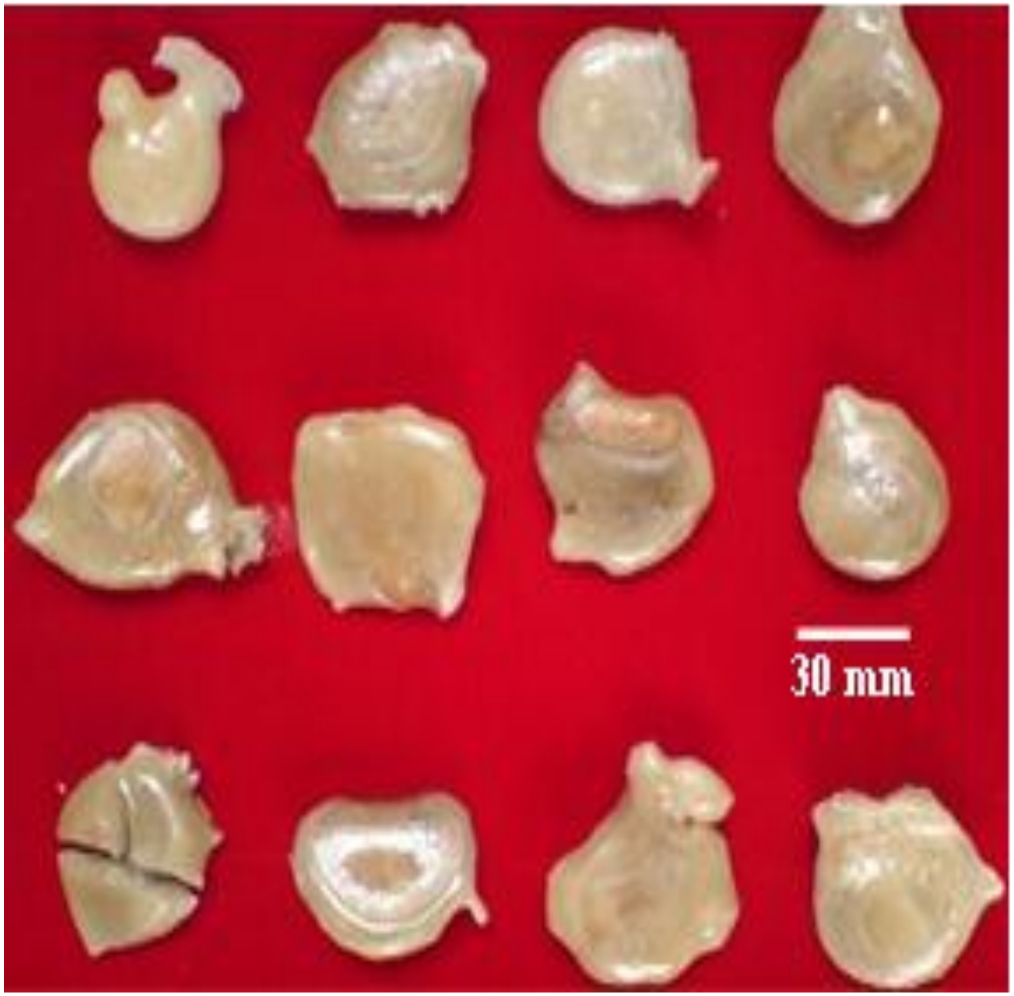
TRANSFERRED ARC PLASMA (TAP) MELTING

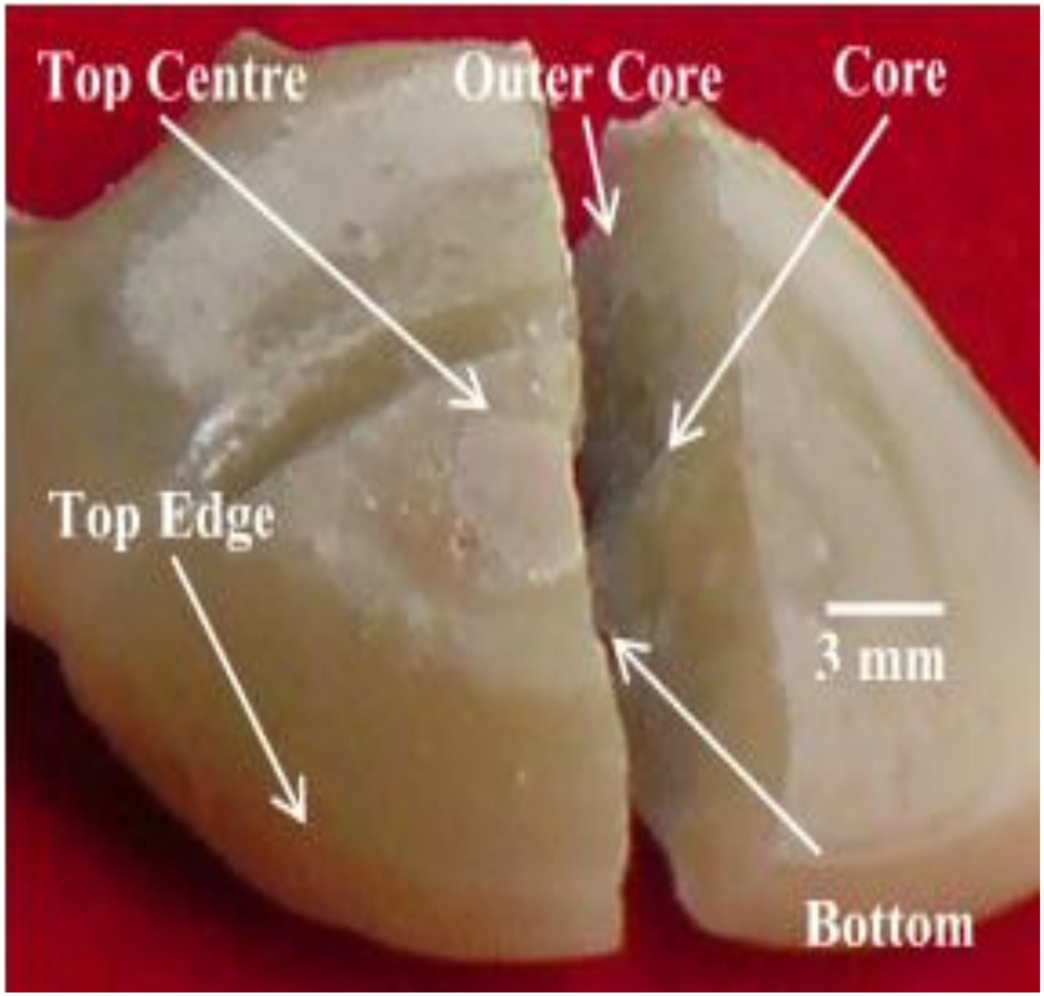
- synthesis of high melting point materials and to mass produce of powders.
- pellets were charged and fired.
- it takes 10 minutes to synthesise from 30 grams of pellets.





TRANSFERRED ARC PLASMA (TAP) MELTING (CONT)



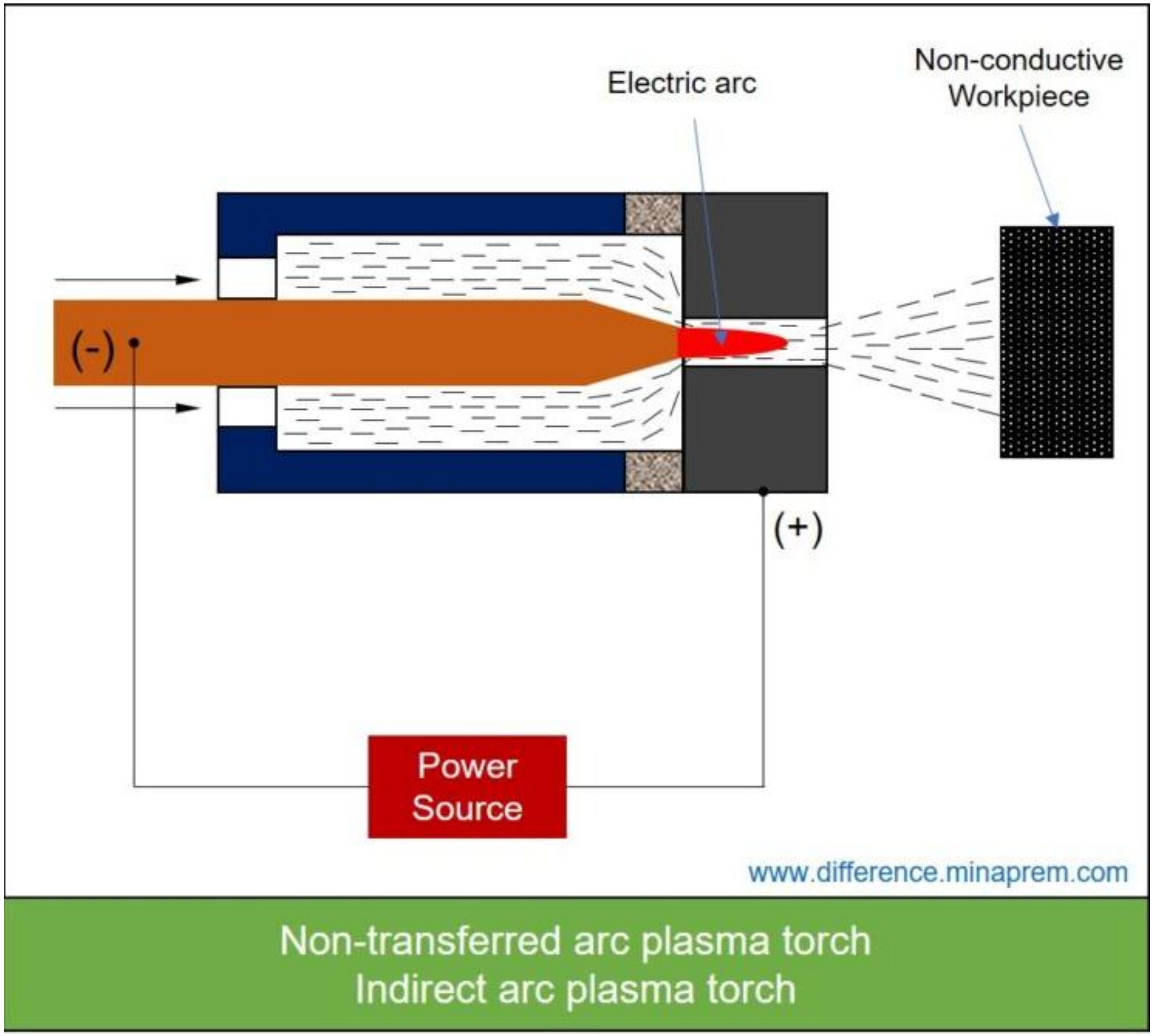


TAP melted nuggets.

locations of the nugget

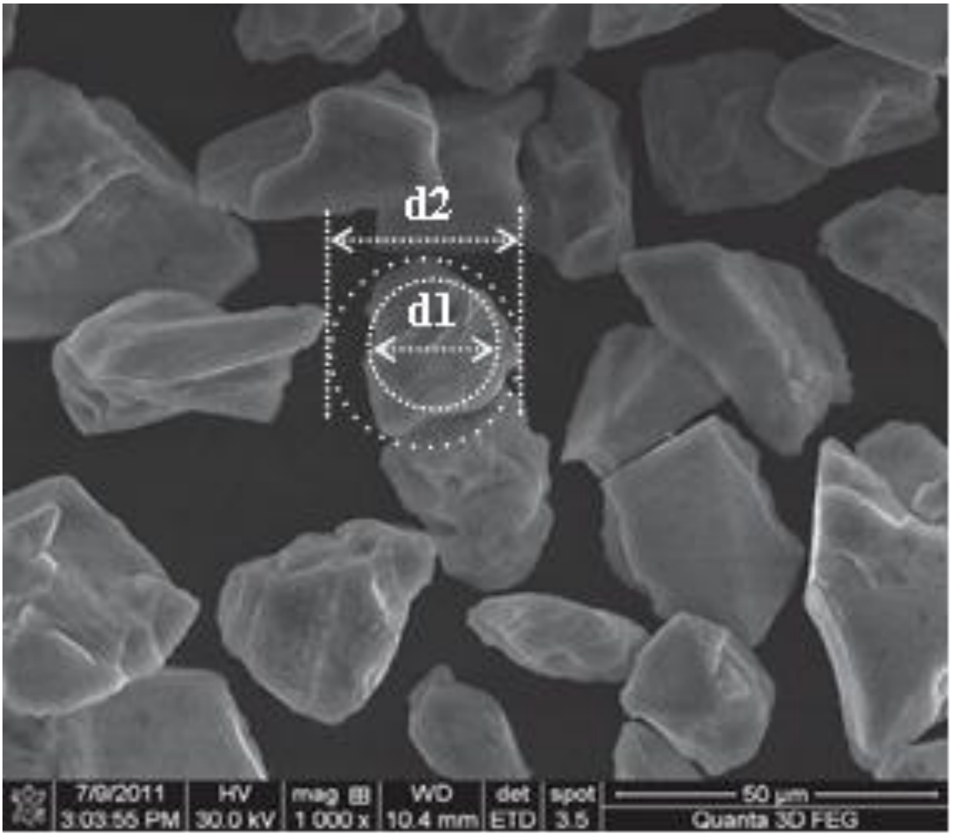
PLASMA SPHEROIDIZATION

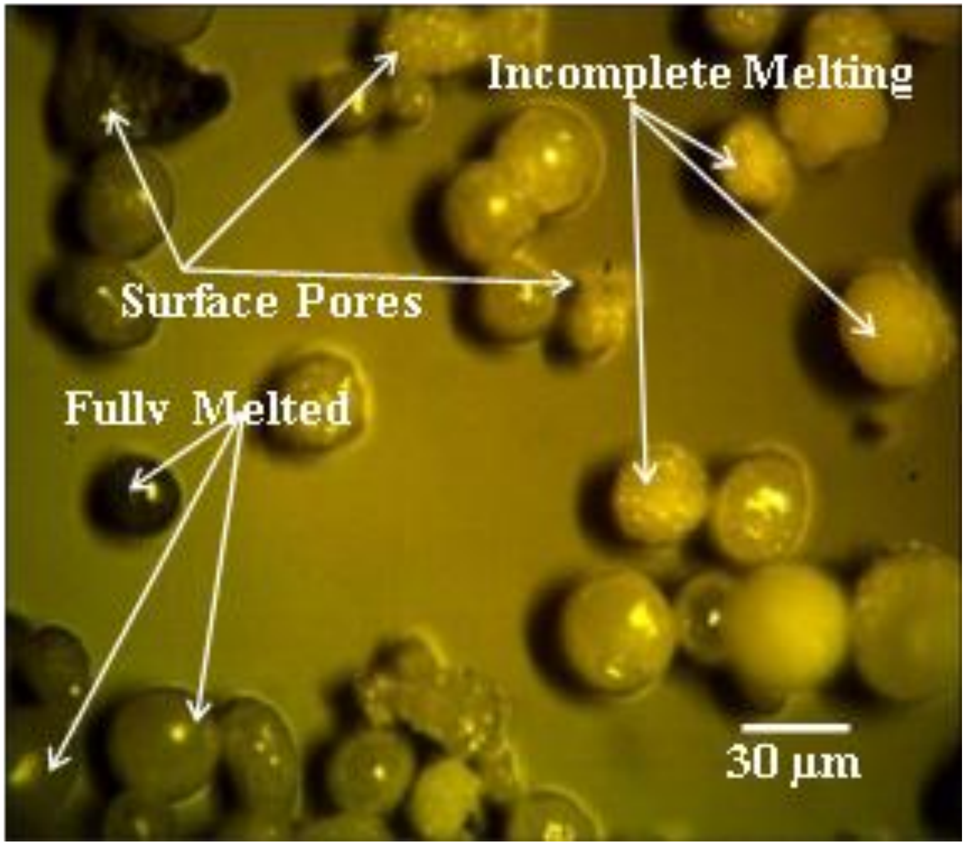
- 10–45 µm size
- thoriated tungsten-cathode
- Copper- anode



PLASMA SPHEROIDIZATION (CONT)

IP= d1/d2 , IP =1 (Hexagonal), IP= 1.67 (ELLIPSOID)
S%= B/A *100
A- No of Powder Particles, B- Amount of spherical particle

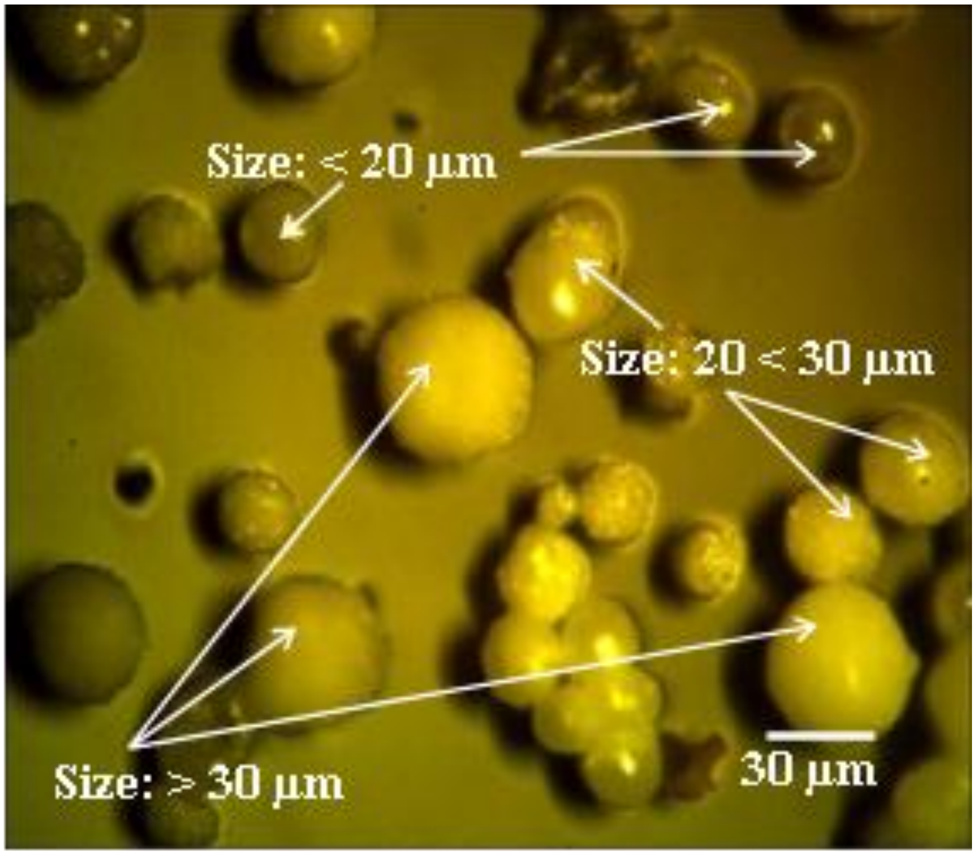




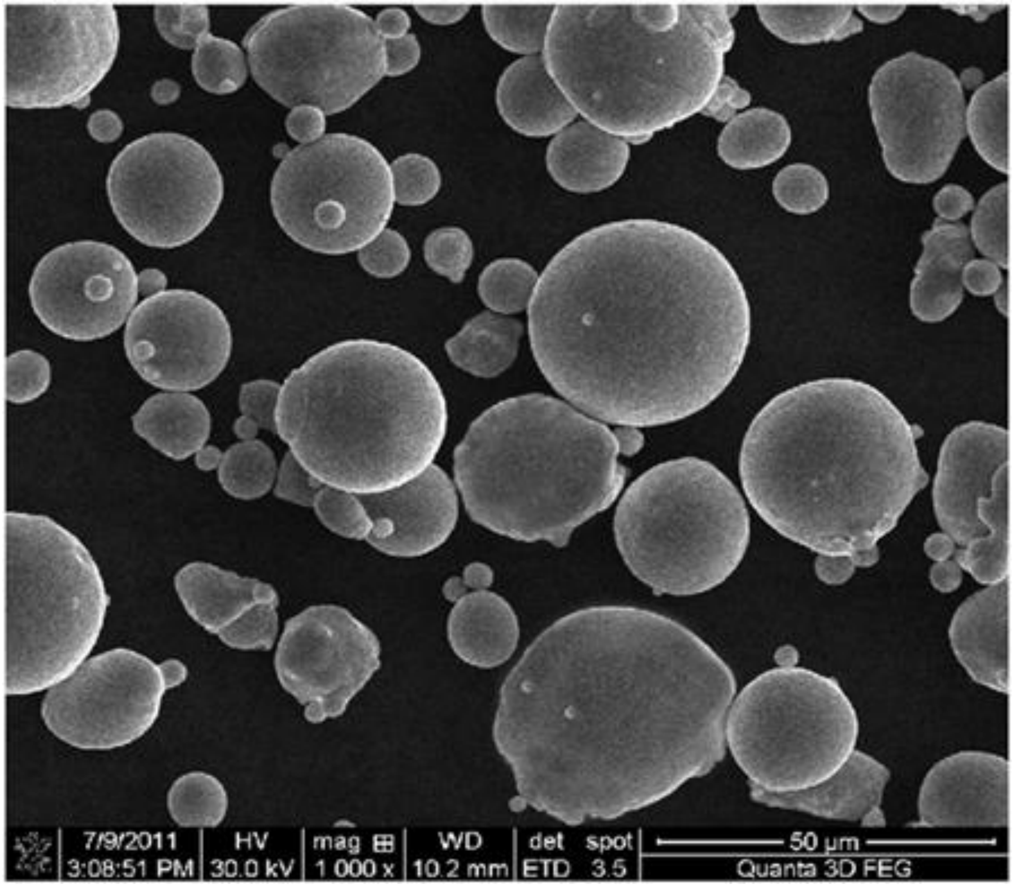
Raw powder.

Spheroidized powder at 23 kW.

PLASMA SPHEROIDIZATION (CONT)



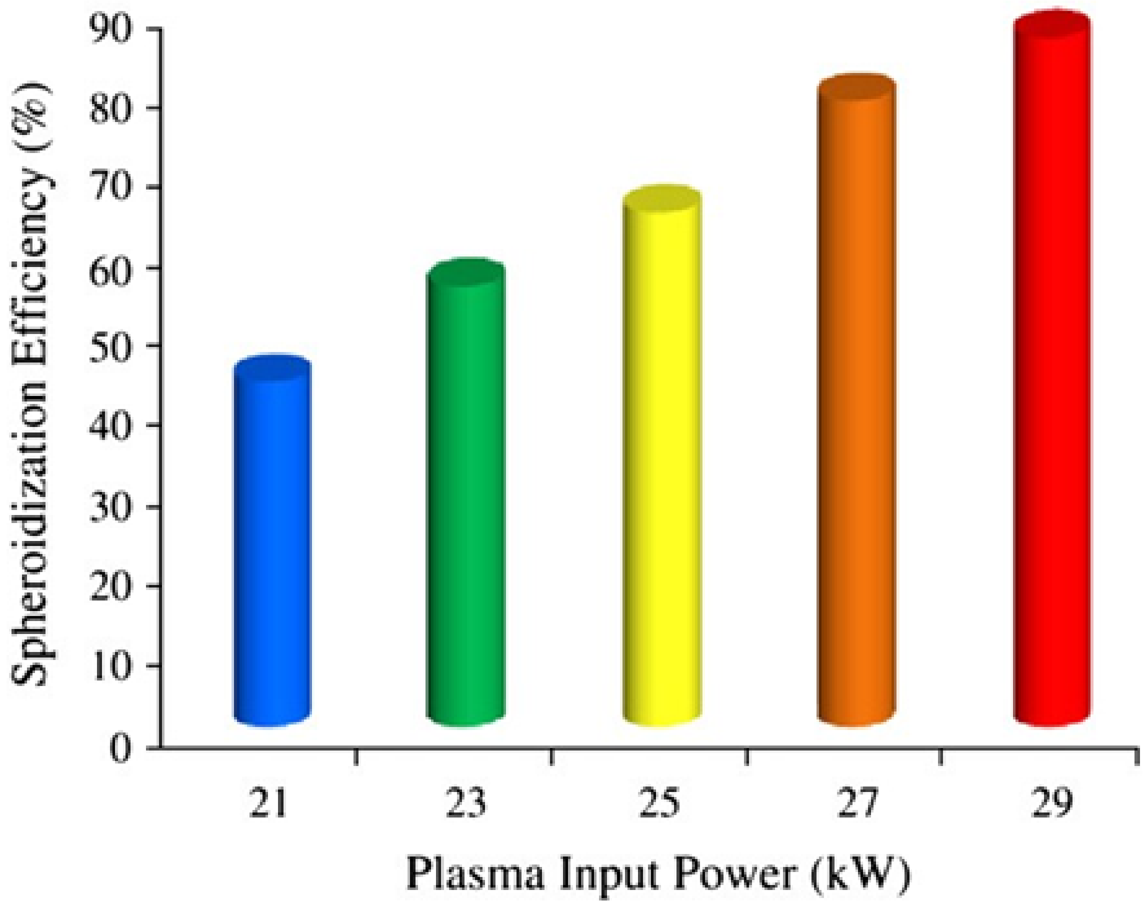
Spheroidized powder at 25 kW.



Spheroidized powder at 27 kW (Optimum Condition).

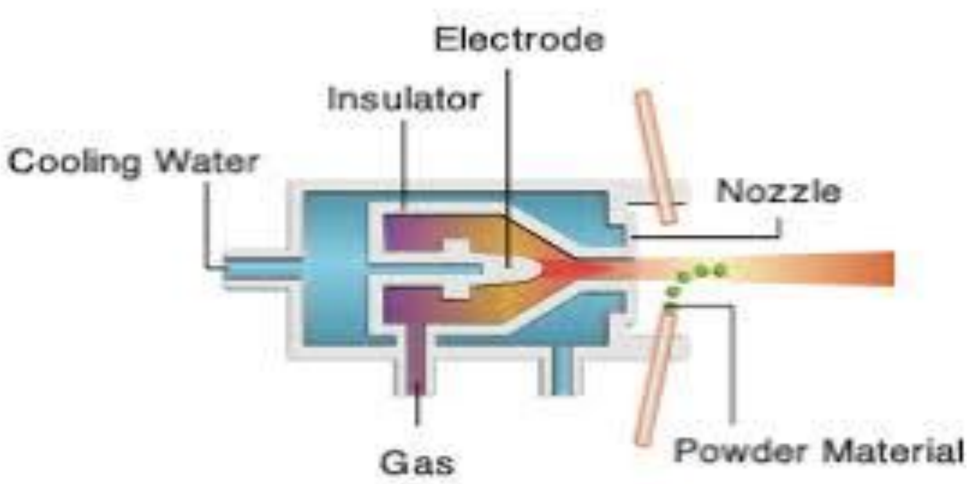
PLASMA SPHEROIDIZATION (CONT)

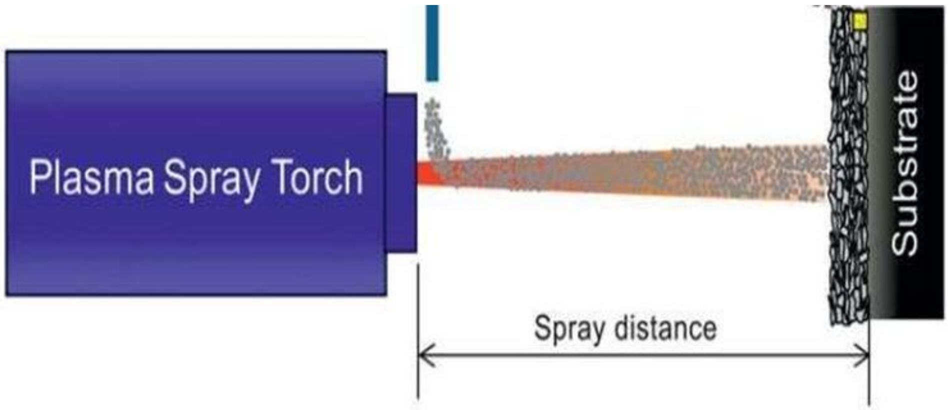
- 27 kW-optimum parameter
- 78% of the powders-spheroidized.



PLASMA SPRAY DEPOSITION

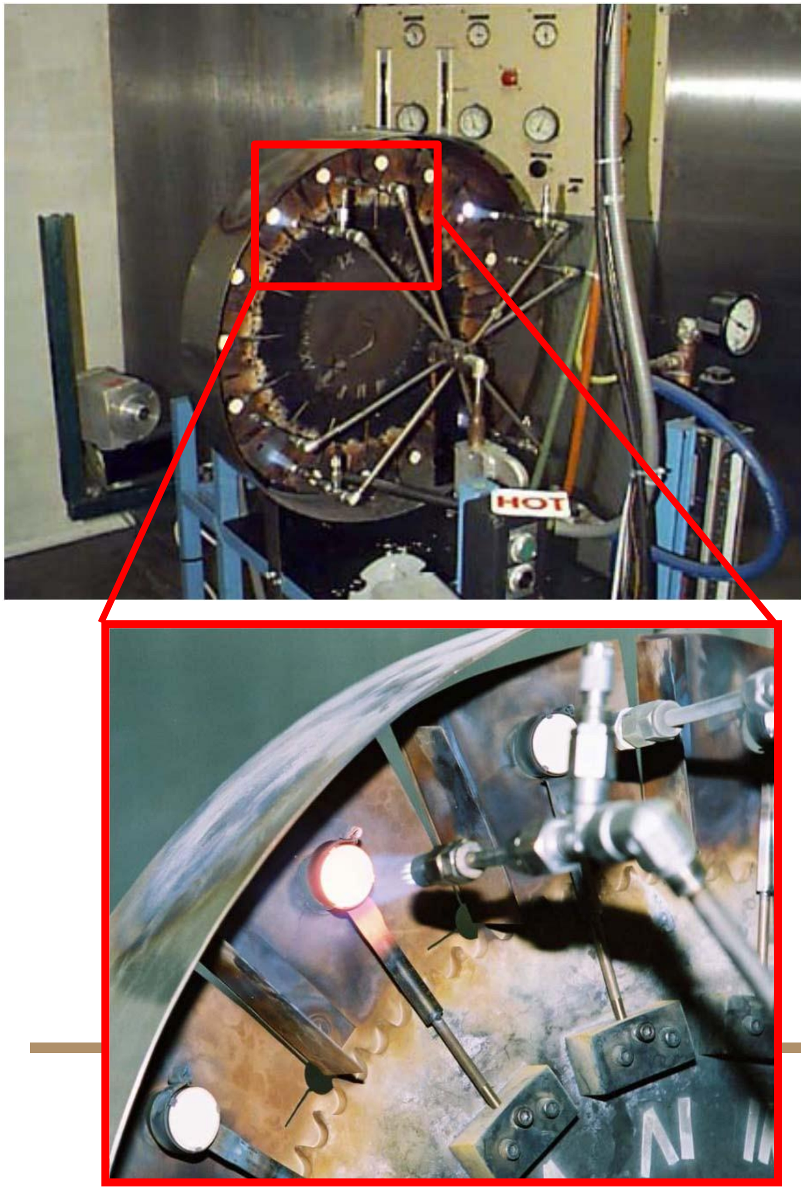
- Inconel 738 (IN 738) -Nickel-based super alloy substrate
- bond coat was not used.
- 32 set of coating by process parameter
- 4 types of substrates





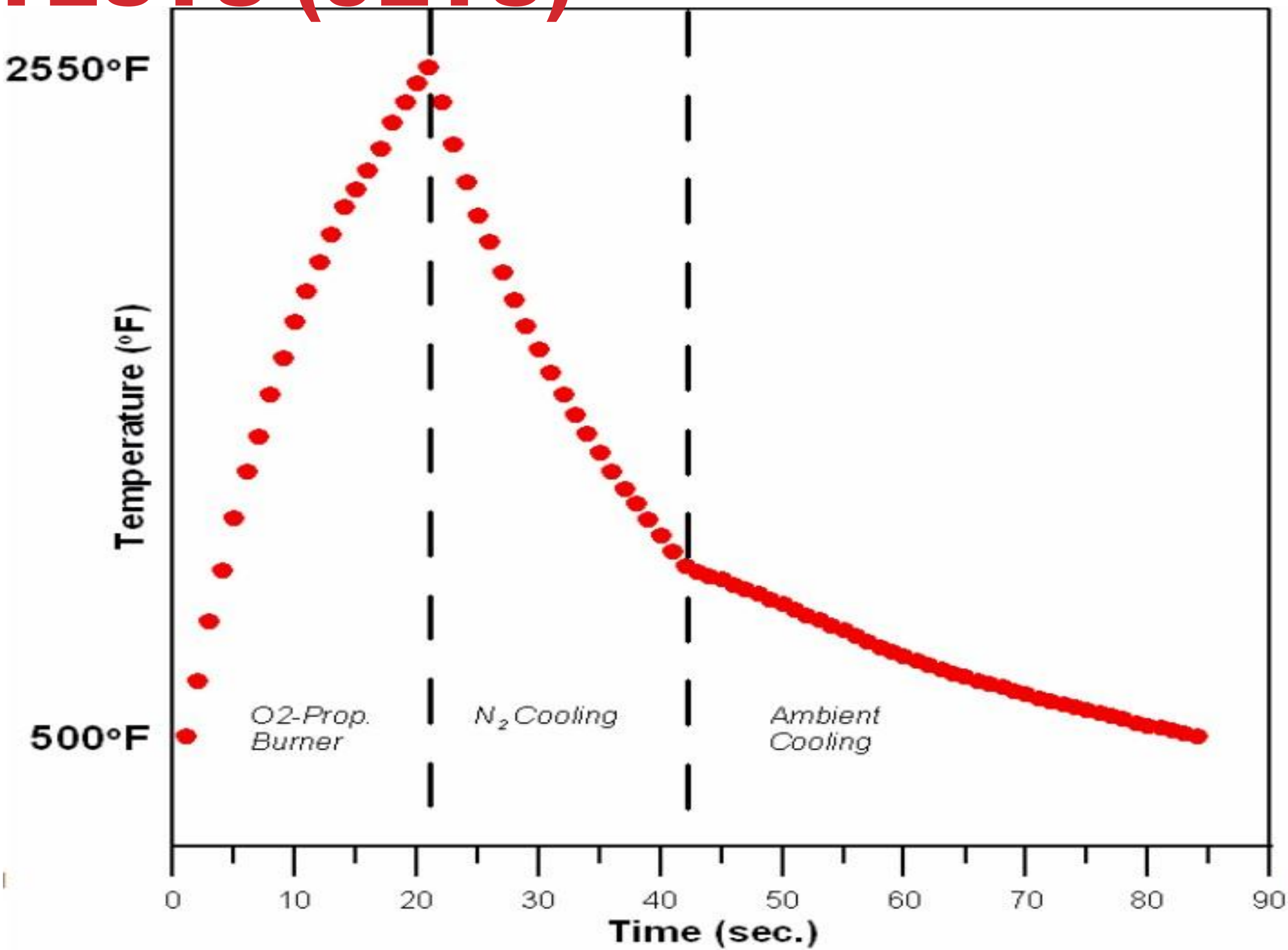
TESTING OF TBC FAILURE

JET ENGINE THERMAL SHOCK TESTS (JETS)



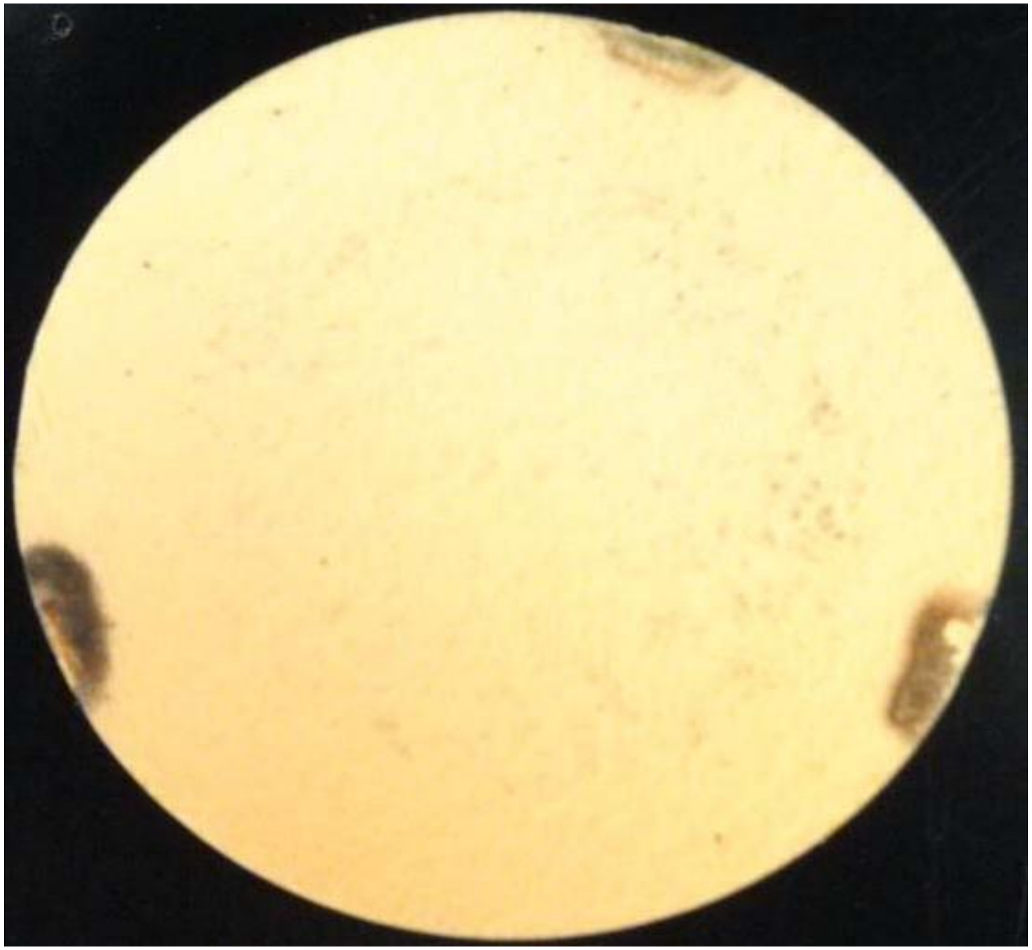
- Jet engine thermal shock (JETS) tests are conducted to investigate the thermal cycling performance.
- For ex. TBC samples are heated to 2250 oF (1232.2 oC) at the center for 20 s, and then cooled by compressed N_2 cooling for 20 s, and then ambient cooling for 40 s.
- Temperatures are measured by thermal couple and pyrometer.

JET ENGINE THERMAL SHOCK TESTS (JETS)



TESTING OF TBC FAILURE

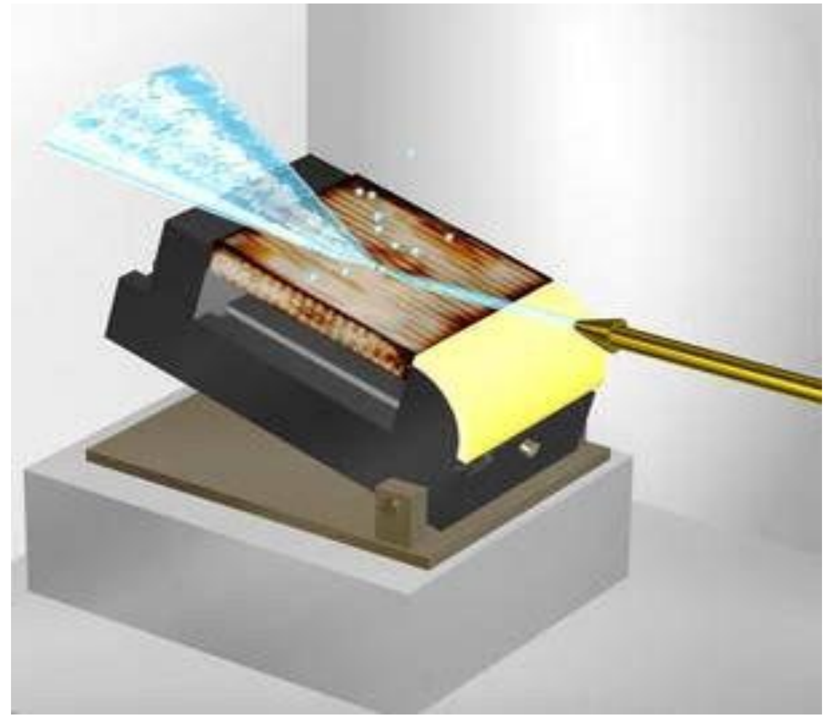
JET ENGINE THERMAL SHOCK TEST (JETS) RESULTS



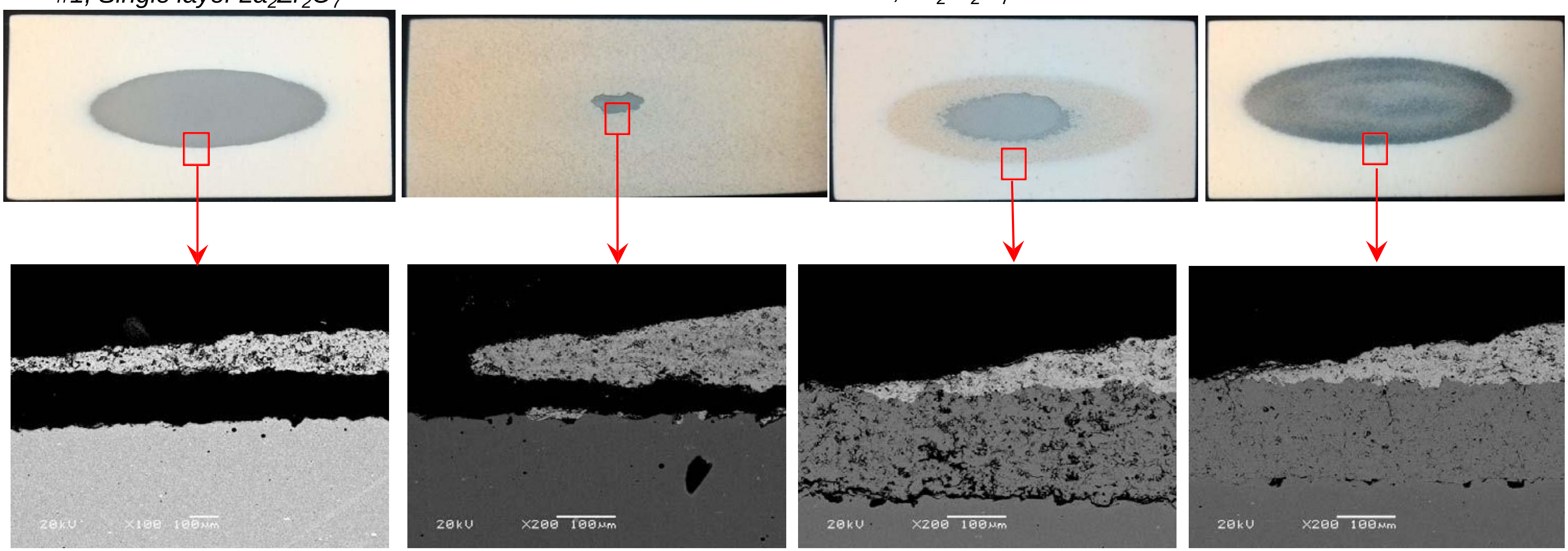
#2, Porous 8YSZ

EROSION TEST

- Erosion is a secondary cause of TBC failure
- 600±0.2g alumina sands with a diameter of 50 μm
- Spray rate 6 g/s; duration 100 s; spray angle 200



#1, Single layer $La_2Zr_2O_7$ #2, Porous 8YSZ. #3, $La_2Zr_2O_7$ +Porous 8YSZ #4, $La_2Zr_2O_7$ +Dense 8YSZ

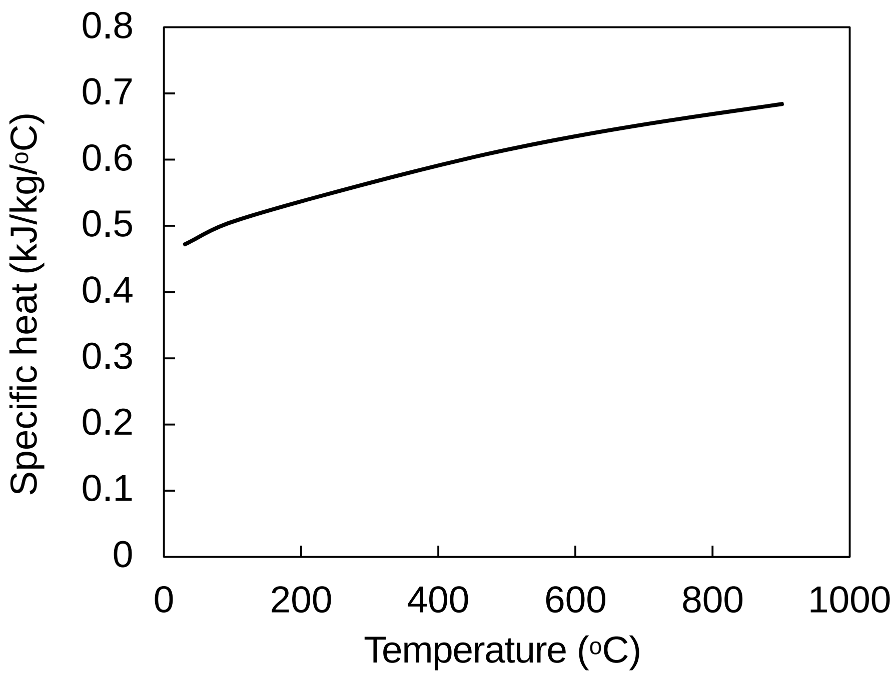


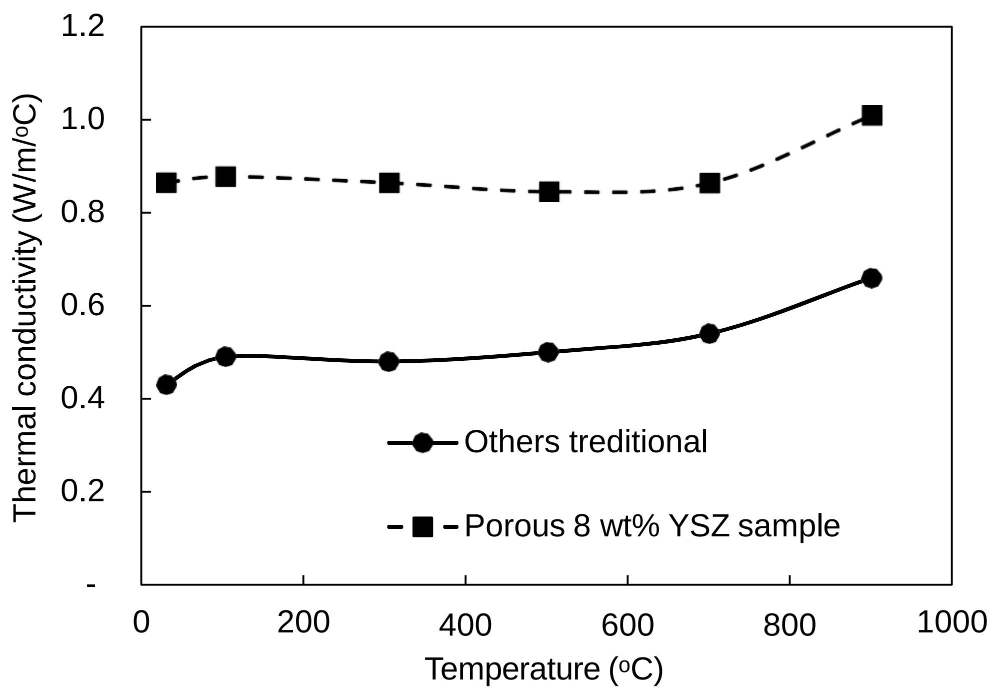
THERMAL CONDUCTIVITY

Thermal conductivity is determined from thermal diffusivity D_{th}, specific heat capacity C_p, and measured density ρ:

$$k = D_{th} \cdot C_p \cdot \rho$$

Thermal diffusivity is measured using laser flash diffusivity system (TA instrument DLF1200). Specific heat is measured by analytical method (TA instrument DLF1200)





SUMMARY

- YSZ powder, coating microstructure and chemistry characterizations show that is stable at high temperatures, which makes it suitable for TBC applications.
- double-layer coating with porous 8YSZ and have better thermal shock and thermal cycling performances
- The layered topcoat architecture is believed to be a feasible solution to improve thermal strain tolerance.

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REFERENCE

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THANK YOU