Chapter 3

Scope and Objectives

3.1 Motivation

In order to improve the reliability and durability of hot section metal components in an advanced aircraft and land based turbine engines and to enhance engine performance, thermal barrier coatings (TBCs) were applied on the surface of these components. The two main processes used to deposit top ceramic coat are atmospheric plasma spray (APS) and electron beam-physical vapor deposition (EB-PVD) whereas the BC may be deposited by various methods such as APS, EB-PVD, low pressure plasma spray (LPPS), high velocity oxy-fuel spray (HVOF) and chemical vapor deposition (CVD). APS is a versatile thermal spray process; however, melting of feed stock particles, flattening and solidification of plasma sprayed particles impinging on a substrate surface are very complex phenomena involving rapid changes in the dynamic and thermal state of the molten particles that depend on many factors. Ceramic materials by virtue of their high melting points and chemically inert nature are used for many high temperature applications. The thermo-mechanical properties of plasma-sprayed coatings are very strongly dependent on the microstructure, and this may be controlled by manipulating the parameters controlling the plasma spray process [63].

The development of ceramic materials for wear and erosion resistance and thermal barrier and high temperature corrosion resistance, is an ever expanding area of applied materials research. Alumina, alumina-titania, yttria stabilized zirconia, refractory carbides and nitrides are extensively used for many wear, erosion resistance and high temperature corrosion resistance applications. For high temperature thermal barrier coating and molten metal containment applications, Yttria stabilized zirconia,
containing 6-8 wt. % yttria is frequently used. This material (YSZ) has been identified as the most preferred TBC material after extensive research work spanning over the last two and half decades and still the research continues to further enhance capability. However, the maximum surface temperature for these coatings is limited to about 1200 °C for long-term operation [64].

To overcome the above problems, some novel ceramic materials with lower thermal conductivity and better reliability at high temperature have been developed as candidate materials for future TBCs. Some of the promising materials, which are being investigated, include zirconium oxide with an addition of pentavalent oxides such as Ta$_2$O$_5$ and Nb$_2$O$_5$. Lanthanum aluminate is another attractive material, which is characterized by thermal conductivity value comparable in magnitude to that of YSZ and mechanical properties better than those of YSZ. Strontium and barium zirconates with perovskite structure have also been investigated. Great interests have been focused on the synthesis of pyrochlore type rare earth zirconate ceramics and found that Lanthanum Zirconate (La$_2$Zr$_2$O$_7$) is a very promising candidate for TBC applications.

Recent R&D efforts have indicated that Lanthanum Zirconate (LZ) is a promising top layer coating material for TBC applications. This material shows low thermal conductivity and good thermal stability up to 1400 °C. Thermal cycling experiments also have shown encouraging results [65].

3.2 Scope

The use of TBCs can result in a significant temperature decrease between the hot gas and the surface of these components. In the next generation of advanced engines, further increases in thrust-to-weight ratio will require even higher gas temperatures. This means that the surface temperatures of the components will
increase. In order to meet this ambitious goal, three major methods can be used. The first is to ameliorate the cooling technique. However, the excessive internal and external cooling will be harmful to the overall thermal efficiency of the engine and engine performance. The second method is the use of more advanced superalloys, but the melting point of the superalloys clearly marks the limit for future developments. The third method is to explore new generations of advanced ceramic TBCs with much lower thermal conductivity.

At present, thermal barrier coatings (TBCs) of Y₂O₃ stabilized ZrO₂ (YSZ) coatings are widely used to protect the hot section parts of aircraft and the land–based turbines by reducing the temperature of metal substrates. However this standard material has a limited temperature capability due to accelerated sintering and phase transformations at high temperatures. As a result, a worldwide effort has been undertaken to identify new candidates for TBC applications. The number of materials that can be used as TBCs is very limited. So far, only few materials have been found to basically satisfy these requirements and Lanthanum Zirconate (LZ/La₂Zr₂O₇) is one such material. From the literature review, it was found that the synthesis of LZ was made mostly using co-precipitation, sol-gel, hydrothermal and hydrazine routes. Hence, a new technique to produce a bulk amount of lanthanum zirconate with time and cost effectiveness is needed. Further, a systematic studies on the tests involving coating characteristics such as porosity, microhardness, Young’s modulus, tensile bond strength, co-efficient of thermal expansion, thermal conductivity and thermal cycling of APS deposited LZ coatings are very limited. Hence, this thesis focuses on developing the LZ based thermal spray grade powder and coating using thermal plasma process and comparing the performance of LZ coating and YSZ coating, using the aforementioned tests.
3.3 Objectives

The main objectives of the present investigations are:

✓ Preparation and characterization of thermal spray quality lanthanum zirconate powder using Transferred Arc Plasma (TAP) melting technique.

✓ Studying the effect of plasma spray parameters on plasma sprayed LZ coating characteristics such as porosity, microhardness and Young’s modulus.

✓ Developing empirical relationships to predict porosity, microhardness Young’s modulus for YSZ and LZ coatings, incorporating APS parameters.

✓ Optimizing plasma spray parameters for YSZ and LZ coatings.

✓ Selection of suitable thermal spray process (APS or HVOF) to deposit NiCrAlY bond coat.

✓ Comparative performance evaluation of plasma sprayed YSZ and LZ coatings.