ABSTRACT

Today titanium carbide has become an important ceramic reinforcement as it possesses many suitable properties such as high melting temperature, high hardness, high modulus, higher strength, superb chemical stability, good electrical conductivity and better wear and corrosion resistance. Titanium carbide reinforced Al matrix composites occupy a unique position in the family of metal matrix composites due to their excellent stiffness, wear resistance, strength-to-weight ratio with good mechanical properties. The most common applications of these composites are in commercial sectors, aerospace and aviation, automobile, industrial and engineering sectors. TiC reinforced polymer matrix composites are also important because of their high strength and hardness, higher friction and wear resistance. One of the key restricting factors in the application of above composites is relatively high cost of TiC.

There are different methods for preparing titanium carbide powder such as carbothermal reduction of titanium dioxide (TiO_2) powders by using carbon or carbonaceous organic material, direct carburization reaction between metallic titanium and carbon, carbothermal reduction of carbon-coated titanium dioxide, sol–gel and microwave carbothermal reduction methods at low temperature and gas phase reaction of $TiCl_4$ with appropriate gaseous hydrocarbons. However, direct reaction of metallic titanium and carbon is an expensive process due to high cost of metallic titanium used and high energy required for the process. Also titanium chloride used as precursor for TiC preparation is an expensive material. Among all these processes, the most widely used process for commercial production of titanium carbide is carbothermal reduction of titanium dioxide in the presence of carbon. TiO_2 can be derived from ilmenite ($FeTiO_3$), which is abundantly available in nature in comparison to the scarce and costly natural rutile. TiC can be produced directly by carbothermal reduction of ilmenite concentrate eliminating all intermediate process of TiO_2 production.

Therefore, the present work has been carried out with the following objectives;

- *To prepare TiC powder from an abundantly available raw material ilmenite, which is a major Ti bearing mineral, in an extended transferred arc DC thermal plasma reactor using graphite electrodes.*
- *To characterize the as synthesized TiC powder and compare with an available commercial TiC powder.*
- *To develop Al-TiC composites by reinforcing plasma produced TiC powder in aluminium matrix by using powder metallurgy method for structural applications and micro-structural and mechanical characterization of the Al-TiC composites.*
- *To prepare polymer matrix composites by reinforcing plasma produced TiC powder in glass fiber reinforced epoxy resin by using hand-lay-up method for applications in highly erosive atmosphere. Characterization and erosion wear study of prepared composites.*

Ilmenite concentrate is considered as a low cost raw material which is abundantly available in nature mixed with the activated carbon homogeneously to be used for the synthesis of TiC. The ilmenite concentrate required for synthesis of TiC powder has been obtained from IREL, Chatrapur and contains approximately 50.5 % of TiO_2 and 34.2 % of FeO. For the synthesis of fine size with high purity TiC particles, the ilmenite concentrate was reduced carbo thermally by direct current extended transferred arc thermal plasma reactor in an argon atmosphere. Thermal plasma processing provides very high processing temperature, at which all the reactants are in monatomic gaseous state and this can reduce the reaction time considerably. The carbothermal reduction of ilmenite concentrate and activated carbon results in the formation of Fe–TiC composites in which globular TiC particles are embedded in the iron matrix. 20 minutes thermal plasma treated time is considered as the optimization period for synthesis of TiC out of ilmenite concentrate. The acid treatment applied to the composite materials results in the separation of Fe and TiC particles. The synthesized TiC powder has been analysed by XRD, FESEM with EDX, Raman spectroscopy and particle size analyzer. The particle size distribution shows that the average particle size is in the order of 10 μm. The TiC powders obtained from this experimental technique are very much comparable to the available commercial powder.

The TiC powders obtained by this method reinforced in aluminium and polymer matrix materials to make composites. Hot pressing method is used for fabrication of Al matrix composites (commercial Al powder taken from SRL Pvt. Ltd.) in which the plasma synthesized TiC powder is used as the reinforcement. The composites were prepared by varying TiC volume fraction from 5 to 20 % in Al- matrix. The maximum bulk density of 2.97 g/cm^3 has been achieved for 20 Vol. % TiC-Al composites. The detection of only two phases in the XRD patterns of the composites indicates that no reaction between matrix and reinforcement to form additional phases has occurred in the current consolidation conditions (hot pressed at 673 K and 400 MPa). Microstructural examination shows a uniform distribution of TiC particulates in the matrix and the presence of minimal micro porosity. The composite sample shows encouraging room temperature mechanical properties with improved young's modulus over that of the matrix. The elastic modulus was enhanced from70 GPa to 88.78 GPa by increasing the volume content of TiC from 0% to 20%. Vickers hardness values have been increased from the matrix to the composites. The yield strength and the ultimate tensile strength have increased from 107 and 320 MPa for the sample with 5 Vol. % TiC particles to 205 and 360 MPa for the composite containing 20 Vol. % reinforcement respectively. On the other hand, the strain has decreased from 47.5 to 27% respectively. Al-TiC composites prepared by this method are suitable for structural and industrial applications, like other Al based MMCs.

Titanium carbide (TiC) filled hybrid composites were prepared by hand- lay- up technique followed by light compression moulding using epoxy resin (Epoxy LY 556) as the matrix material and woven E-glass fibers as the reinforcement. Density and hardness measurements of these composites along with erosion wear study have been carried out. With the incorporation of filler particulates into the composites, the mean hardness is seen to have improved from 29 Hv for 0 % TiC composite to 53 Hv for 20% TiC composite. The erosion wear performance of the composites shows significant improvement with the addition of TiC filler. The erosion rate of the composites is generally correlated with many operating parameters like impact velocity, impact angle and erodent size. Angle of impingement is one of the strong factor on which the erosion rate depends. In the present study, erosion wear rate of glass-epoxy composites filled with TiC particle with varying composition from 0-20 wt % with different angle of impingement is studied by conducting experiments under specific operating conditions (impact velocity 68 m/s and erodent size

200 micron). The result shows that the maximum erosion takes place at 60^0 showing semi-ductile response to solid particle erosion. It can be concluded that among all the factors, impact velocity is the most significant factor followed by TiC percentage and impingement angle, while the erodent size has the least significance on erosion of the reinforced composite.

To summarize the present investigation on synthesis of TiC powder and TiC reinforced composites comes up with few significant and novel findings. TiC powder has been synthesized directly from ilmenite concentrate within very short period of time by thermal plasma route eliminating a number of intermediate processes. This plasma synthesized TiC powder has been successfully used as reinforcement in aluminium matrix and polymer matrix composites suggesting their possible applications in industries.