Advantages of a wet process for the production of Ti matrix composite reinforced with carbon nano materials by powder metallurgy route

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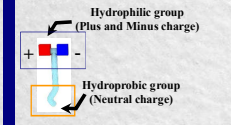
Abstract

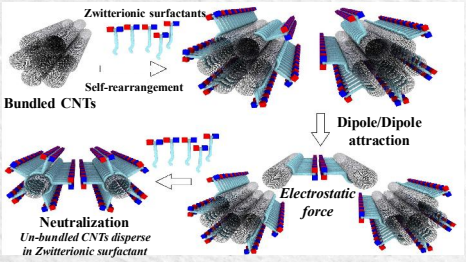
A titanium matrix composite reinforced with different carbon nano materials i.e. carbon nanotubes, acetylene black and carbon black was fabricated by spark plasma sintering (SPS) and hot extrusion. Carbon nano materials were added for the in-situ formation of TiC fine dispersoids during the SPS process. Fine Ti powders were coated with carbon materials by a wet process using a zwitterionic solution containing 0.5wt.% of carbon materials. The coated Ti powders were consolidated by hot extrusion. The mechanical properties of the composites were remarkably improved by adding a small amount of carbon nano materials. The increases in the yield stress of the extruded fine Ti was 50.7%, 41.2% and 64.2%, while the tensile strength increases 24.8%, 22.5% and 35.7% for the carbon nanotubes, acetylene black and carbon black reinforcement, respectively, compared to those of extruded pure Ti with no reinforcement.

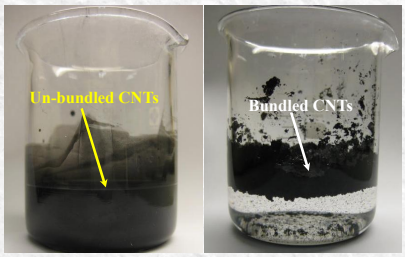
Separation Mechanism of Bundled CNTs

Zwitterionic surfactant

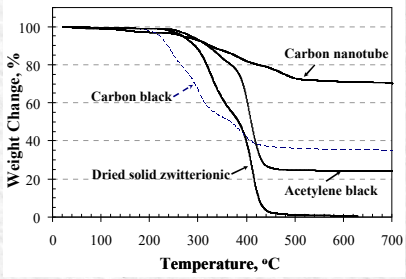


The neutral charge of hydrophobic group will attract to the surface of carbon nano particles, while the electrostatic interaction between positive and negative charges of hydrophilic group is attracted together.





Dispersed in Zwitterionic **Agglomerated in Water**



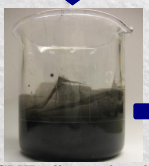
Determination of debiding temperature by TG analysis

Results

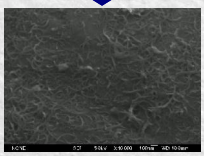
Coating carbon nano materials

Ti powders

Wet processing

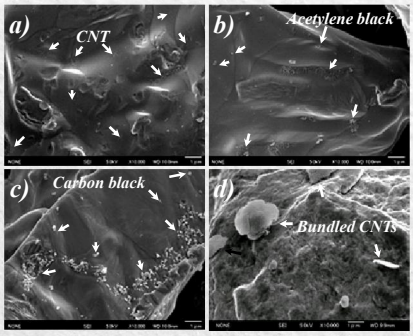


Debinding process: 600°C, 60min

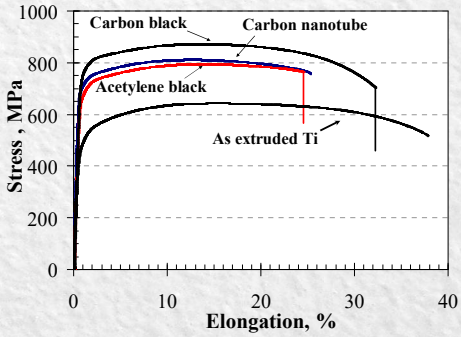


CNTs dispersion in Zwitterionic solution

Individually and uniformly dispersed CNT on the Ti powder surface



Ti powder coated by a) CNTs, b) acetylene black and c) carbon black particles via a wet process, compared to that mixed with CNTs by a planetary ball mill

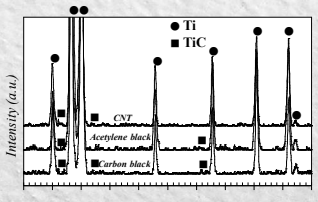


Stress-strain curves for P/M extruded titanium composites reinforced with in situ formed TiC particles.

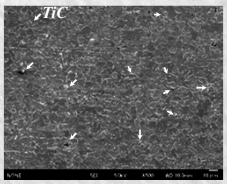
Mechanical properties and chemical analysis results of the extruded Ti/TiC composites

Extruded Ti samples	Grain size µm	TiC size µm	YS MPa	TS MPa	e/ %	HV	Chemical analysis (wt.%)			Incremental stress per 0.1wt.% of Carbon, MPa	
							C	O	N	YS	TS
Ti/CNTs	5.8	1.9	683 [20]	808 [11]	27.2 [10.4]	306	0.245	0.35	0.0110	98.7	69.1
Ti/Acetylene black	8.1	2.1	640 [28]	793 [12]	28.8 [16.5]	286	0.121	0.33	0.0070	171.6	133.9
Ti/Carbon black	5.8	3.0	744 [14]	878 [18]	29.3 [12.0]	340	0.162	0.38	0.0092	194.0	154.0
Ti without reinforcement	4.1	-	453 [25]	647 [19]	37.3 [1.7]	261	0.012	0.21	0.0100	-	-

[ ] : Maximum – Minimum value.



XRD patterns of the extruded Ti composite reinforced with ***carbon nano materials***



Microstructure of extruded Ti composite reinforced with CNTs revealed the distribution of *in situ* formed TiC particles throughout the Ti matrix

Conclusion

A wet process, the zwitterionic surfactant solution containing CNTs, acetylene black and carbon black particles, was used to coat the Ti powders. The coated Ti powders revealed a good distribution of non-agglomerated carbon reinforcing phases on the surfaces. Consequently, the in situ formed TiC particles were highly distributed throughout the Ti matrix, resulting in the increased mechanical properties. Furthermore, the effect of grain size, oxygen and nitrogen contents did not significantly improve the mechanical properties of the extruded Ti composites materials.