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Titanium (TiO_2) coated nano-carbons in an aluminium matrix for weight reduction applications

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Introduction

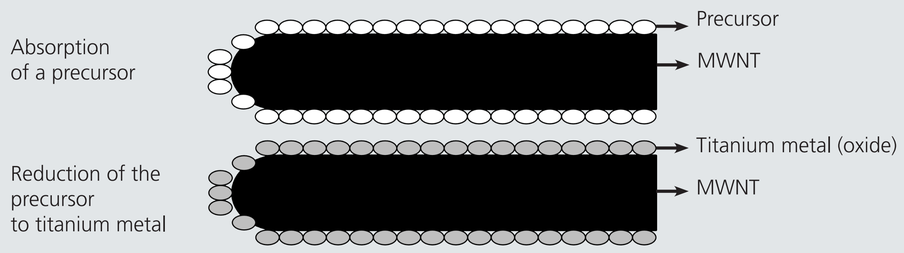
One of the most urgent needs in automotive industry is the reduction of weight. Light cars produce less CO_2 and use less energy. In the case of electro vehicles, weight reduction is vital to extend the driving range – thus lightweight material is a key for modern mobility.

By modifying the nano carbon (NC) surface through coating (via CVD- or Sol-Gel-procedure) it is possible to further increase the interfacial bonding as well as protecting the NC from detrimental composite manufacturing processing.

The metal-oxide coatings applied via these two procedures differ in structure and degree of coating.

CVD Coating Methods

Requirements for the process[1]



450-475 °C: $2\ TiCl_3\ (s) \longrightarrow 2\ TiCl_3\ (g) \longrightarrow TiCl_2\ (g) + TiCl_4$

~1000 °C: $\hookrightarrow \frac{1}{2}\ Ti + \frac{1}{2}\ TiCl_4\ (g)$

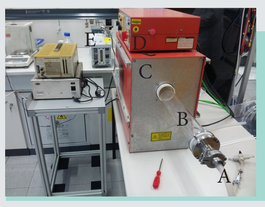
- Vapours of $TiCl_3$ are formed by heating up
- TiCl3 coordinates well to CNTs => base for homogeneous coating
- TiCl3 (gaseous) is adsorbed on the surface of CNTs
- Disproportionation: a specific type of redox reaction in which a species is simultaneously reduced and oxidised to form two different products
- Disproportion $TiCl_3$ into $TiCl_2$ and $TiCl_4$
- Vacuum applied for continuous removal of $TiCl_4$ and promotion of $TiCl_3$-vapor
- Reduction of titanium chlorides by hydrogen released by decomposition of TiH_2

Conversion of $TiCl_3$ into Titanium

Two possible routes:

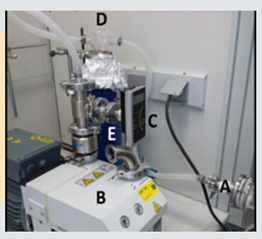
- 2. Disproportion of $TiCl_2$ into Ti and $TiCl_4$
- Reduction of titanium chlorides by hydrogen*

* Thermal decomposition of added TiH_2 or use of mixtures of hydrogen and argon



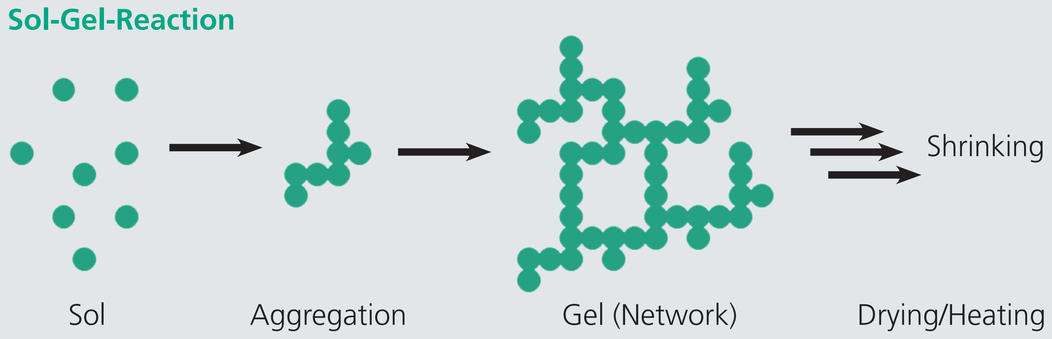
A = Supply for formic gas
B = Quartz tube
C = Reactor
D = Temperature controller
E = Pump

A = Discharge line from reactor
B = Pump
C = Vacuum controller
D = Cooling trap
E = Liquid N2 cooling tower



Sol-Gel Coating Method

Sol-Gel-Reaction



Alkoxide sol-gel-process consists of two coupled steps:

- Hydrolysis of Alkoxide
- (Poly-)Condensation (= Release of water + formation of the oxides, transition from „Sol" (dispersed fine particles) to „Gel" (gelatine))

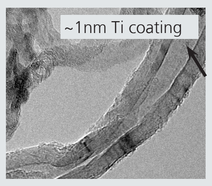
Hydrolysis:

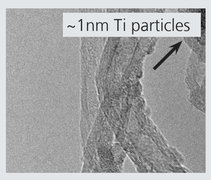
$Ti(OC_2H_5)_4 + H_2O \longrightarrow HO\text{-}Ti(OC_2H_5)_3 + HOC_2H_5$

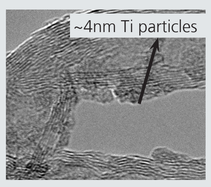
Condensation:

$(H_5C_2O)_3Ti\text{-}OH + HO\text{-}Ti(OC_2H_5)_3 \longrightarrow (H_5C_2O)_3Ti\text{-}O\text{-}Ti(OC_2H_5)_3 + H_2O$

Results Sol-Gel TiO_2 Coatings[2]

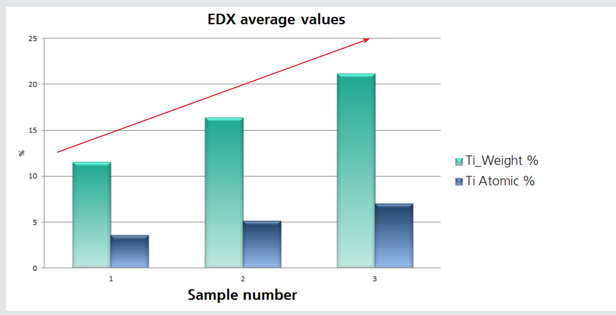


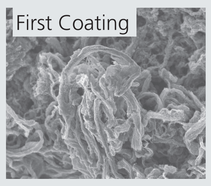


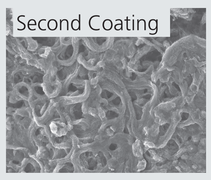


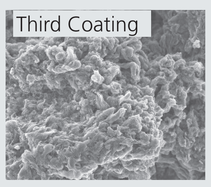
- Titanium tetra-ethoxide
- Absolute ethanol
- Isopropanol
- Nitric acid (64%)
- Distilled water

- Solutions were homogenized under reflux at 80 °C for 1 h with a magnetic stirrer
- Thermally treated at 300 °C for 1 h

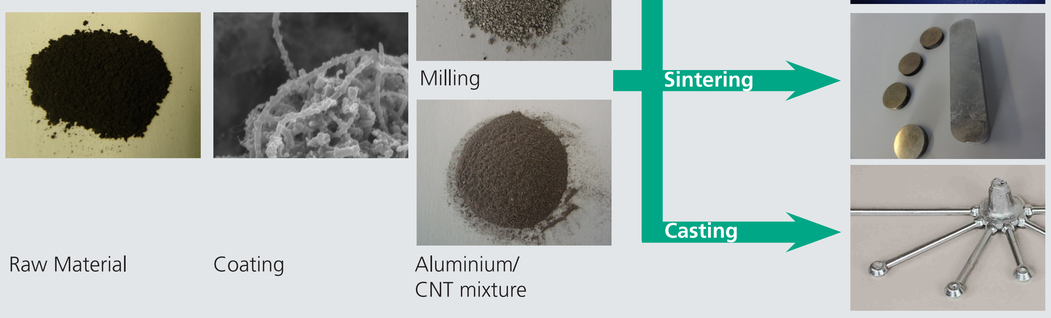




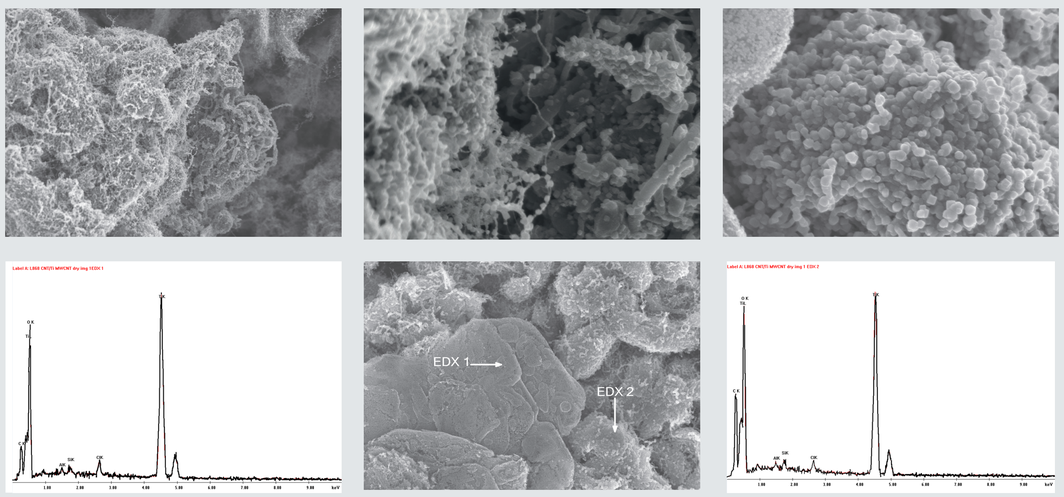




Integration in MMC Matrix

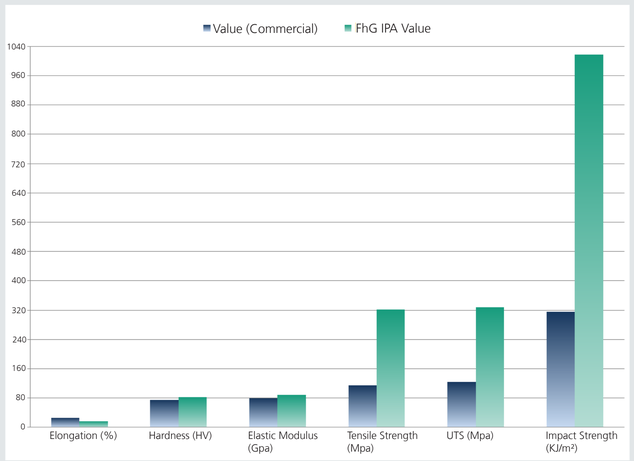


CVD Coating Results



Results MMC Matrix

Commercial Vs. Fraunhofer IPA MMCs



Reference 1: A. Jitaine et al, Carbon, 42, 2004, 1147-1151

Reference 2: Y.h.Wang, Carbon, 48, 2010, 3802-3806