Study of aluminium containing multiwall carbon nanotubes

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Motivation

Nowadays, materials have to meet expectations of new applications at higher levels of performance. There is a need for new combinations of materials that are more efficient, longer lasting, more practical, less costly, and having minimal impact on the eco-system to preserve the planet. Reducing environmental impacts receives more attention today and is a major challenge for humanity. In the field of advanced technology, designing new elaboration techniques is necessary for obtaining high quality materials, always lighter, that exhibit unprecedented mechanical, thermal, electrical, and electronic properties that are required to advance technology, and thus make innovation a key element in such applications. Composite materials containing nanoscale additions, having exceptional properties, do solve some difficult design challenges but are often quite expensive. Their development for specific applications is extending to fields like automotive industries, leisure materials, sports, and environmental protection.

The introduction of multi-walled carbon nanotubes (MWCNTs) into metallic, ceramic or polymer matrices opens interesting perspectives. They result in an interesting reinforcement of the materials and aim at improving their thermo-structural properties. In metallic matrices, MWCNTs bring about unique characteristics that are excellent (low coefficient of thermal expansion and high thermal and electric conductivities). With their low density, excellent chemical stability, high rigidity, resistance to wear, their lightweight, which makes them eco-friendly and reduces their CO2 emissions, and their Young modulus at 1 TPa, MWCNTs are ideal matrix reinforcements.

Sample preparation:

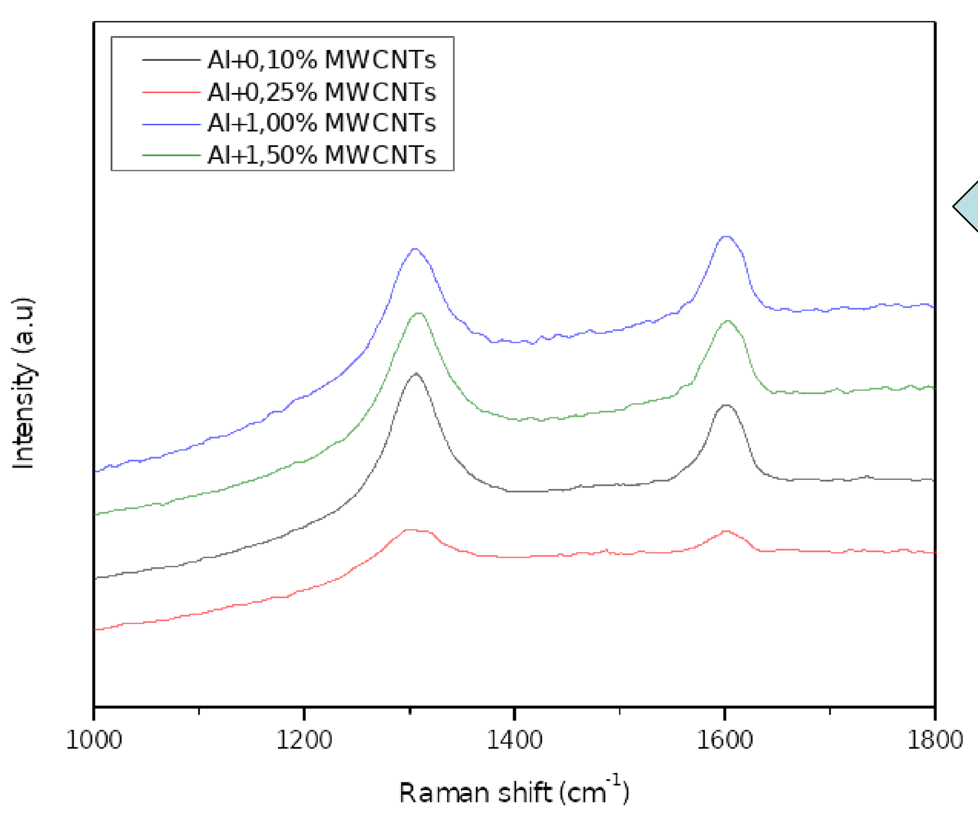
Sample preparation was done by ball milling a mixture of A999 aluminum powder and multiwall carbon nanotube (MWCNTs) powder. The powders were mixed and processed in multiple cycles (cycle time was 60 min) in a planetary mill (acceleration - 50 g, pressure on a particle - 5 GPa). Ball milling allows breaking up the entangled MWCNTs and dispersing them uniformly in the aluminum matrix. At the same time, the diffusion and reaction of aluminum and carbon atoms during ball milling also contribute to improving the bonding of the interface between the MWCNTs and the Al powder grains. In addition, the latter becomes more refined by ball milling. The uniform dispersion of MWCNTs within the Al powder results in composites with improved properties. The MWCNTs used are of average size between 10 and 20 nm. They were prepared by the CVD process in a rotating reactor. Al_2O_3-MoO_3-Fe_2O_3 were used as a catalyst. The carbon source used is propylene. The specific surface area of MWCNTs, calculated by argon desorption, is 200 to 400 m^2/g while their bulk density is 20 to 40 g/dm^3.

Sintering of the pellet obtained from the mixture of the powders was carried out in an argon atmosphere at the temperature T=380°C for 10 min. The obtained materials were subjected to rolling at room temperature for relative deformation in the range of 20-30% after the first pass between the rolls followed by annealing at 900°C in an argon flow. The described cycle was repeated three times. Finally, the samples underwent an 80% thinning, and the final thickness of the ribbons obtained was close to 0.3 mm.

The concentration of multiwall carbon nanotubes used for the preparation of the 4 samples were 0.10, 0.25, 1.00, and 1.50%MWCNTs.

Raman Spectroscopy:

Raman Spectrum of Al+0.10% MWCNTs, Al+0.25% MWCNTs



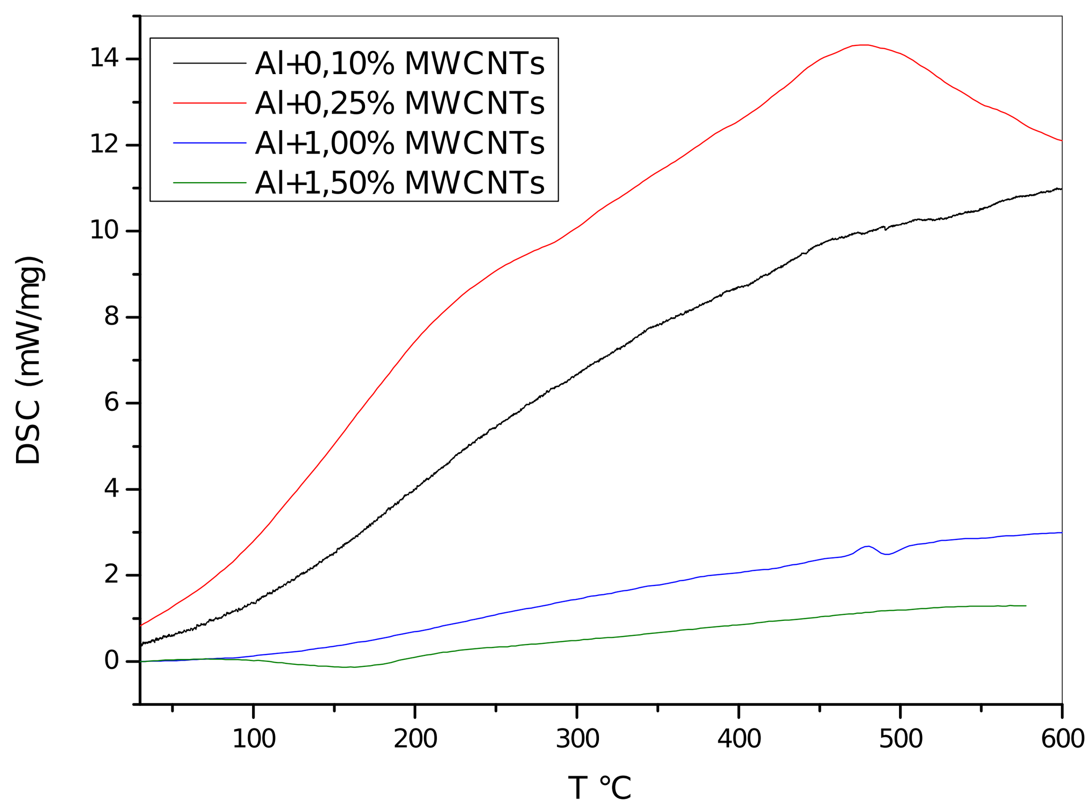
Samples	I_D/I_G
Al+0.10% MWCNTs	0.92
Al+0.25% MWCNTs	1.00
Al+1.00% MWCNTs	1.15
Al+1.50% MWCNTs	1.59

Results

We notice that the ratios ID/IG have increased with the increase in MWCNTs concentration. This means that the quantity of defects has also increased with increasing concentration. This can lead to a destruction of the MWCNTs. on the other hand; the ID/IG values remain included in the domain (0.5, 3) of the literature..

Calorimetry:

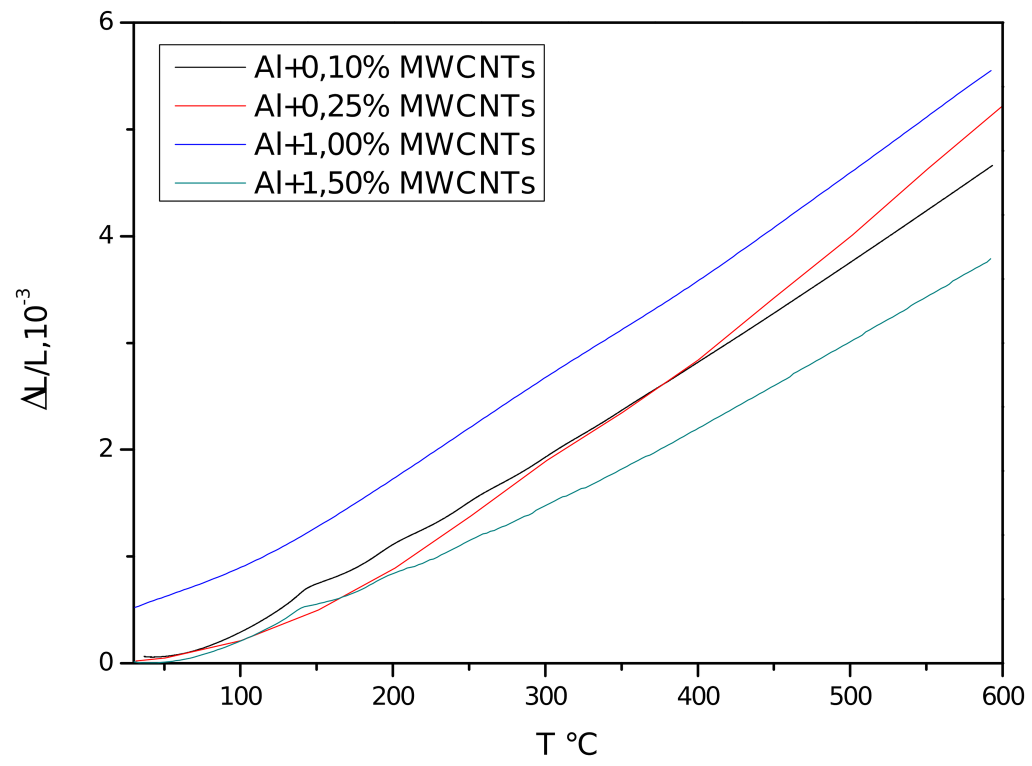
DSC Spectrum of Al+0.10% MWCNTs, Al+0.25% MWCNTs, Al+1.00% MWCNTs, and Al+1.50% MWCNTs



The two highest concentrations led to calorimetric curves having the same shapes. Those of 0.1% and 0.25% MWCNTs gave intense DSC curves. the comparative study between the DSC of the 4 samples shows that the 1.5% MWCNTs nanocomposite has the lowest DSC compared to that of 0.25% which has the highest heat capacity.

Dilatometry:

Dimensional variation ΔL/L of Al+0.10% MWCNTs, Al+0.25% MWCNTs, Al+1.00% MWCNTs, and Al+1.50% MWCNTs.



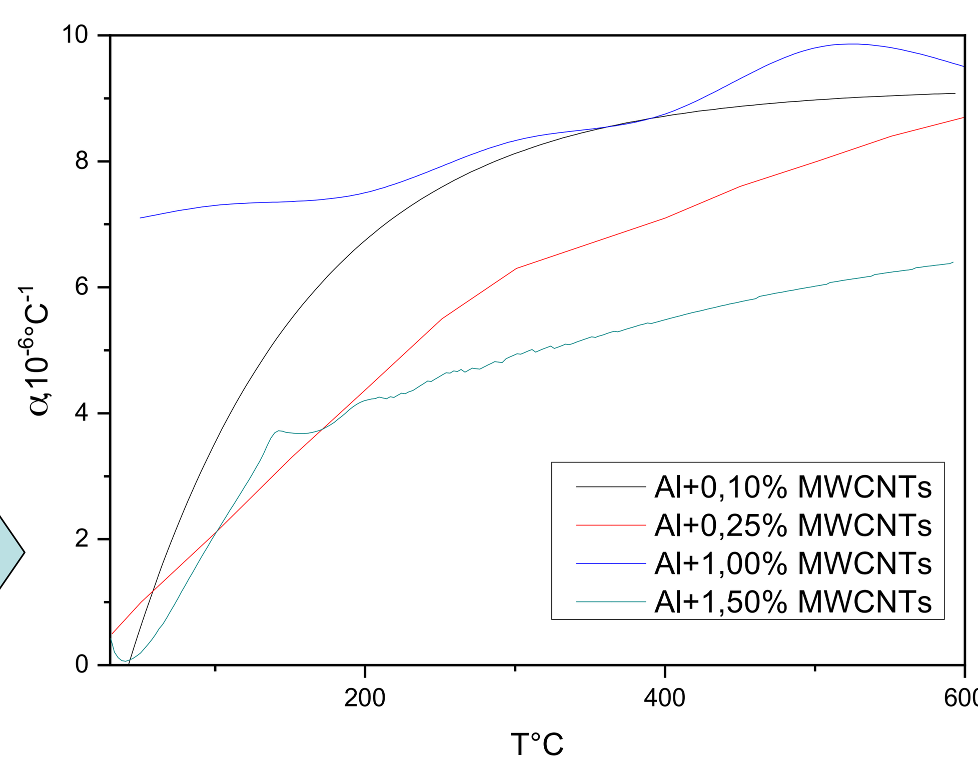
Coefficient of thermal expansion of Al+0.10% MWCNTs, Al+0.25% MWCNTs, Al+1.00% MWCNTs, and Al+1.50% MWCNTs

The curves ΔL/L have practically the same shape over the entire temperature range. We note the existence of an overlap between the curves ΔL/L of the sample of Al+0.10% MWCNTs, and Al+0.25% MWCNTs, these two curves are superimposed in the interval 280-420 °C. This might be related to a similar dispersion of MWCNTs.

Al+1.00% MWCNTs presente the highest expansion values over all the temperature range, while Al+1500% MWCNTs present the lowest ones.

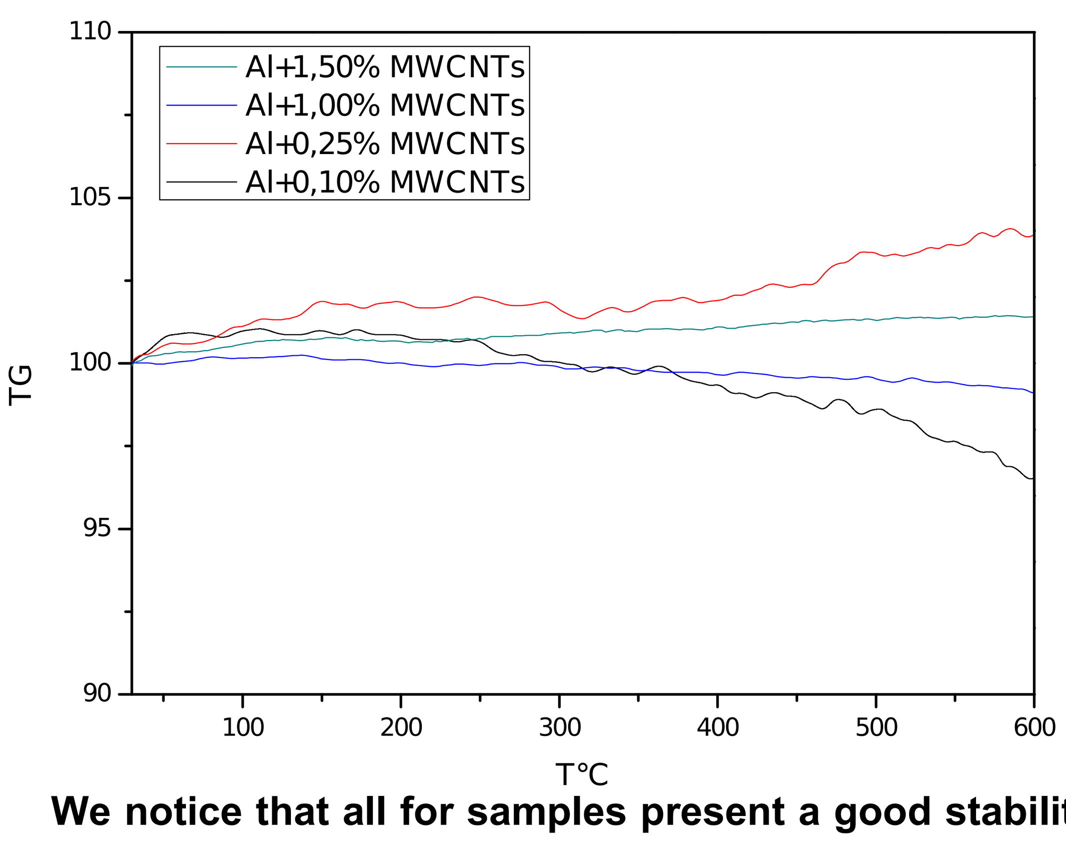
Concerning the coefficient of thermal expansion the curves of 0.1%, 0.25% and 1.50% MWCNTs have practically the same form. That of Al+1.00% MWCNTs presents an almost linear shape compared to the other three curves.

the highest concentration of MWCNTs has led to a significant decrease in the coefficient of thermal expansion



Thermogravimetry:

TG Spectrum of Al+0.10% MWCNTs, Al+0.25% MWCNTs, Al+1.00% MWCNTs, and Al+1.50% MWCNTs



We notice that all for samples present a good stability over the whole temperature range, however, there's some mass change for the samples containing low concentrations of MWCNTs. For the sample Al + 1.5% MWCNTs, the curve shows that the mass remains practically constant over the whole temperature range. We conclude that the introduction of MWCNTs improves the mass stability of the nanocomposites.

Conclusions

•The obtained results in this work have showed that the MWCNTs play a significant role. They are the origin of the drastic decrease in the coefficient of thermal expansion that has an order of magnitude of 8.10^{-6}.

• It is the quarter of that of pure Al and it is comparable to MWCNTs thermal expansion coefficient. This significant drop can be really interesting in the industrial field.