Structure of Al-Cu/C nanocomposites synthesized by mechanical alloying of elemental powders

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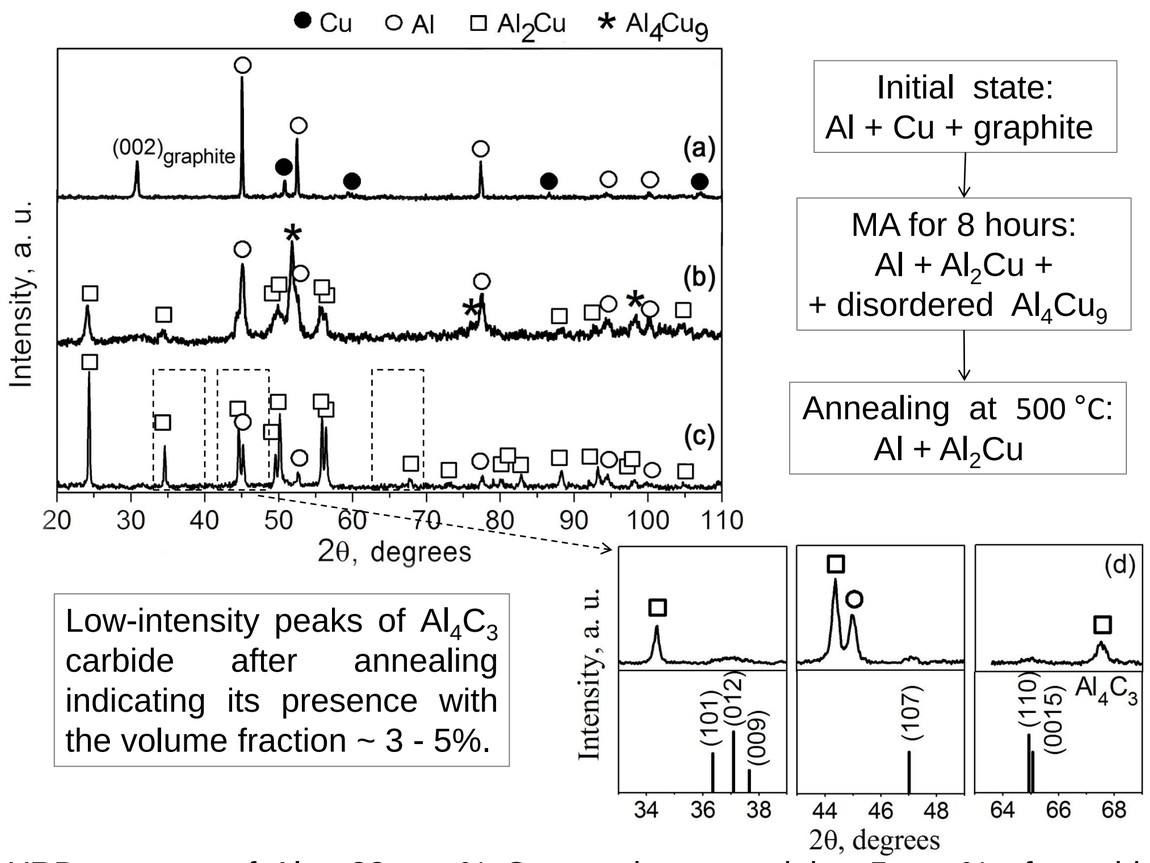
Introduction / Objectives / Aims / Methods

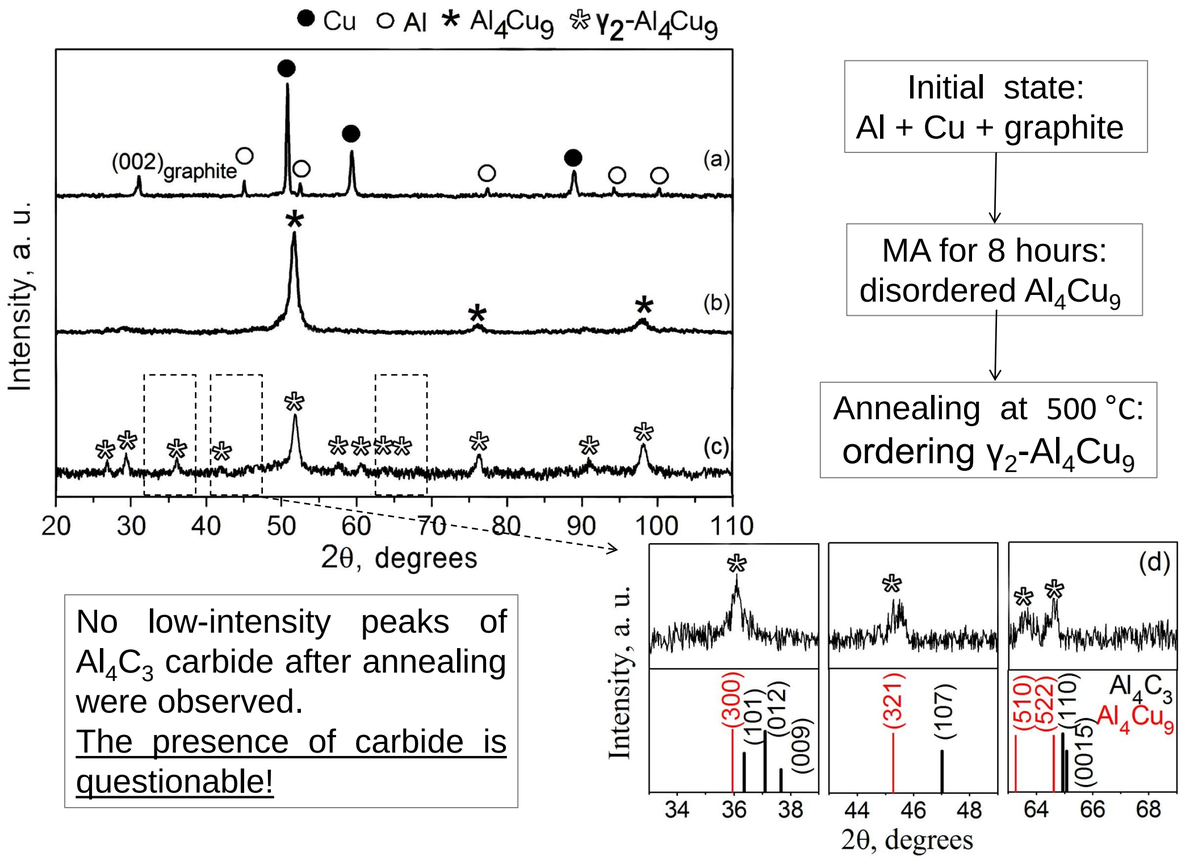
Al-Cu powder composites reinforced with graphite additives are characterized by the improved strength/density relation due to low weight of graphite and appear to be promising candidates to replace conventional aluminum alloys in many applications, such as engine pistons, brake pads, turbine blades, Cardan shafts etc. [1]. Our previous studies considered the influence of 5 wt. % graphite additives on microstructure and mechanical properties of the eutectic powder nanocomposites Al - 33 wt. % Cu after mechanical alloying (MA) and sintering [2, 3].

In this work, we compare the evolution of both structure and phase composition of powder nanocomposites Al - 33 wt. % Cu and Al - 80 wt. % Cu (region of the equilibrium Al_4Cu_9 phase) containing 5 % wt. of graphite additives after MA and heat treatment in the solid-state to specify the changes in structure of graphite particles as well as formation of Al_4C_3 phase and ordering of metastable disordered bcc Al_4Cu_9 phase. The obtained samples were studied using X-ray diffraction analysis (XRD), Raman spectroscopy and nuclear magnetic resonance (NMR).

Phase transformations in powder nanocomposites:

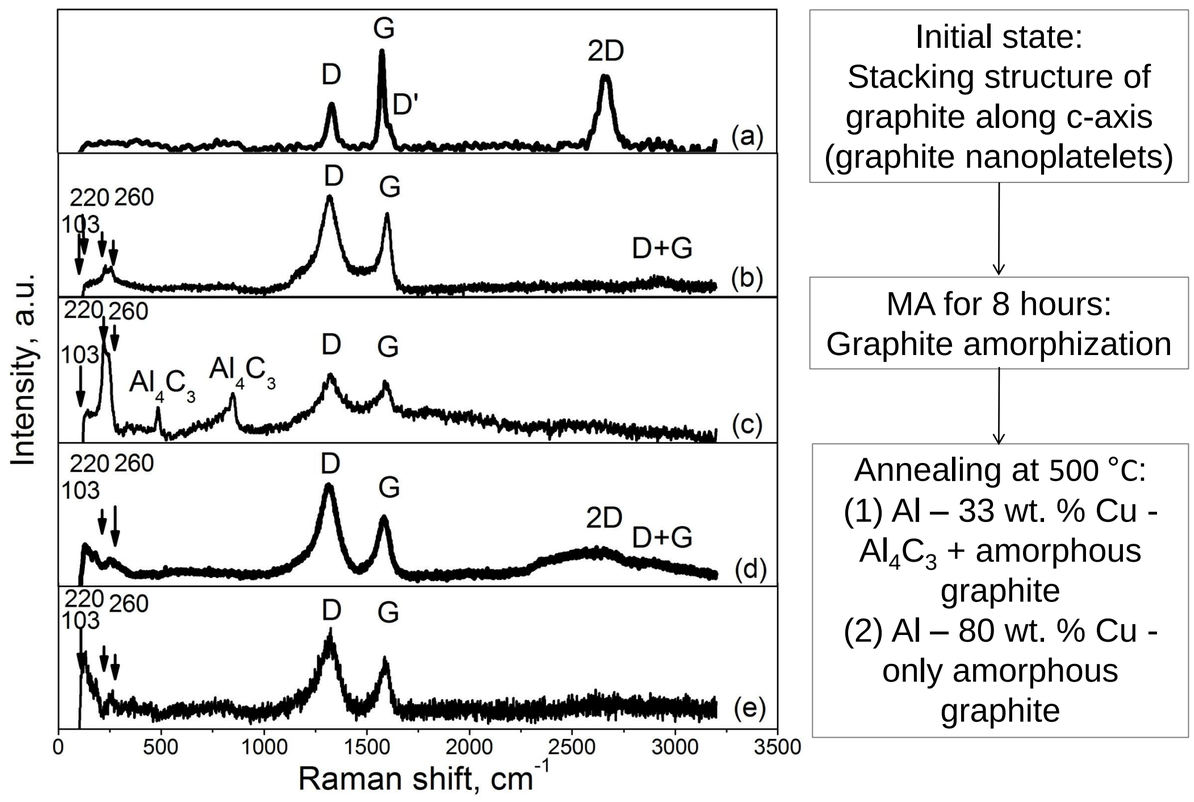


XRD patterns of Al – 33 wt. % Cu powders containing 5 wt. % of graphite powder additives in the initial state (a), after MA for 8 hours (b) and heat treatment at 500°C for 2 hours (c, d).



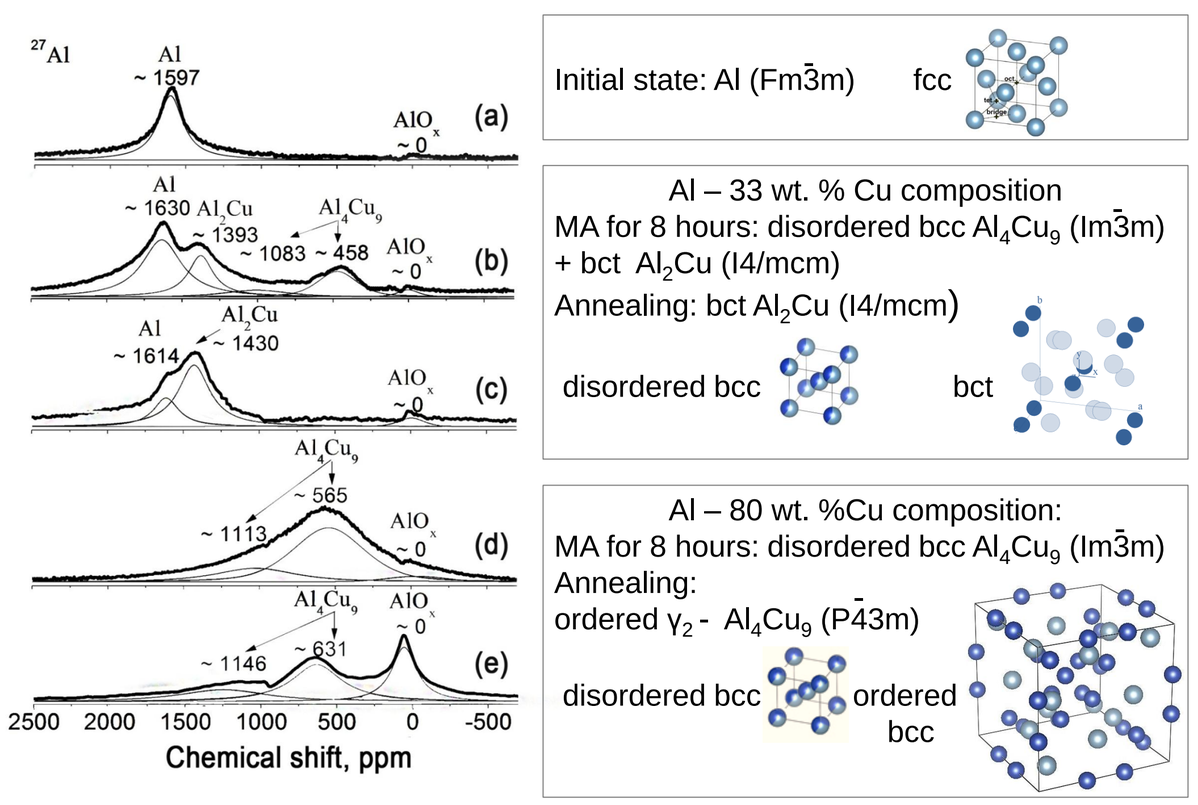
XRD patterns of Al – 80 wt. % Cu powders containing 5 wt. % of graphite additives in the initial state (a), after MA for 8 hours (b) and heat treatment at 500°C for 2 hours (c, d).

Changes in the structure of graphite additives:



Raman spectra of the powders in the initial state, after MA for 8 hours and heat treatment at 500°C for 2 hours of Al – 33 wt. % Cu (a,b,c) and Al – 80 wt. % Cu (d, e) composition containing 5 wt. % of graphite additives.

Stability of disordered Al_4Cu_9 phase:



NMR ^{27}Al static spectra of the powders in the initial state, after MA for 8 hours and heat treatment at 500°C for 2 hours of Al – 33 wt. % Cu (a,b,c) and Al – 80 wt. % Cu (d, e) composition containing 5 wt. % of graphite additives.

Conclusions

Mechanical alloying of Al - 33 wt. % Cu and Al - 80 wt. % Cu powder mixtures containing 5 wt. % of graphite additives resulted in the formation of the phase composition: disordered Al_4Cu_9 phase + non-stoichiometric Al_2Cu_{1-x} phase ($0.012 < x < 0.059$) + supersaturated solid solution Al(Cu); disordered Al_4Cu_9 phase. It was specified that in both cases the graphite additives crystalline structure changed into amorphous one after milling, but the reaction between aluminum and carbon with the formation of ~3–5 vol. % carbide Al_4C_3 was observed only in the eutectic powder nanocomposites after heat treatment. Thus, after heat treatment at 500 °C of the milled powder nanocomposites, the phase composition was Al + Al_2Cu + Al_4C_3 for Al – 33 wt. % Cu and only ordered γ_2-Al_4Cu_9 phase for Al – 80 wt. % Cu composition. In both cases, the formation of the metastable disordered bcc Al_4Cu_9 phase (structural type A2) with different occupations by Cu and Al atoms was observed. The possible scheme of its' ordering into γ_2- Al_4Cu_9 phase (structural type $D8_3$) in the powder nanocomposites Al – 80 wt. % Cu containing 5 wt. % of graphite additives was shown.

References

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