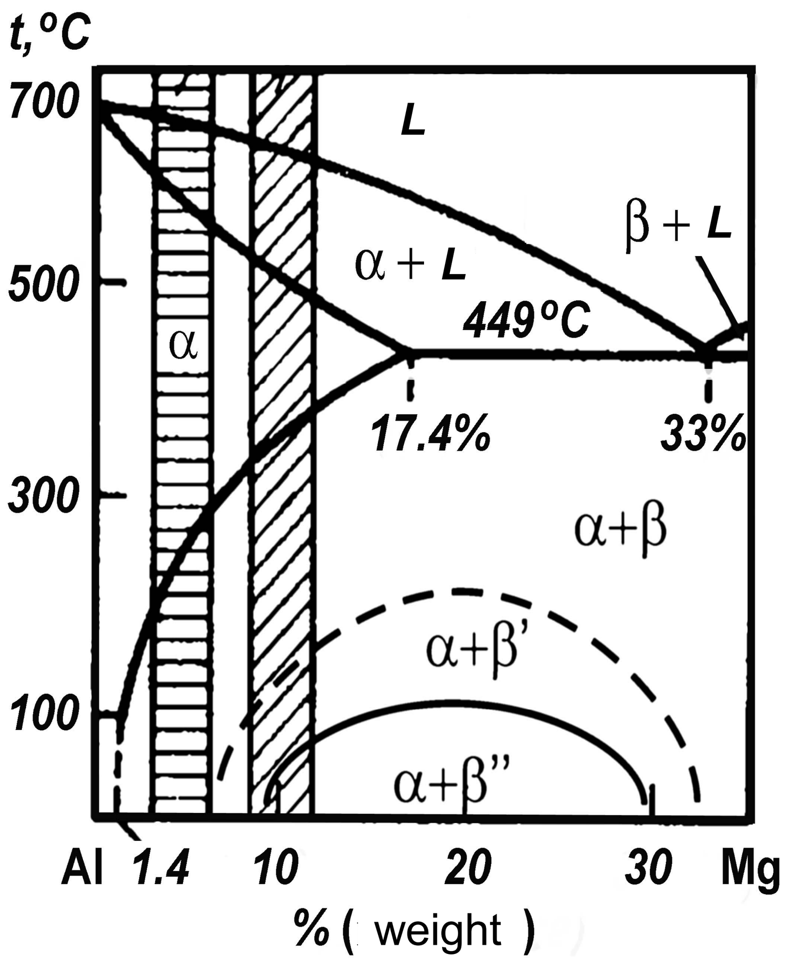
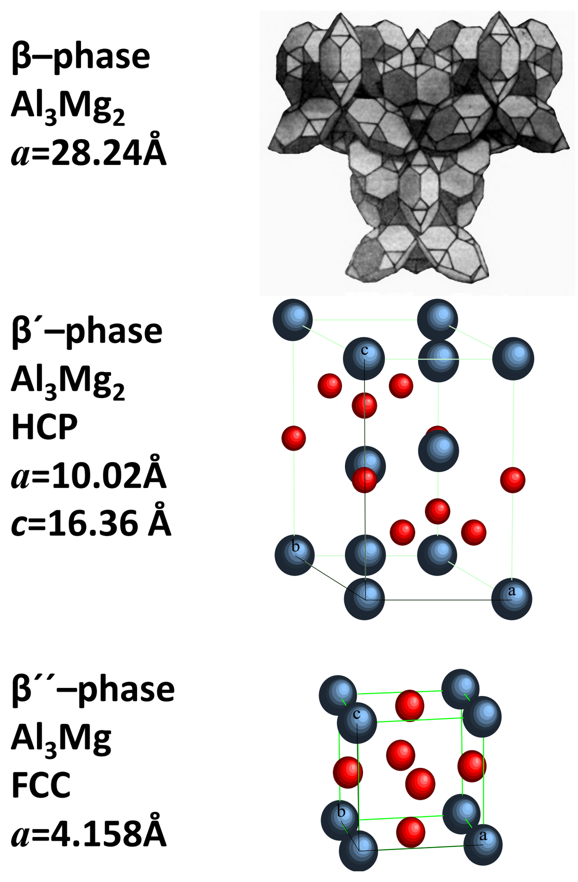
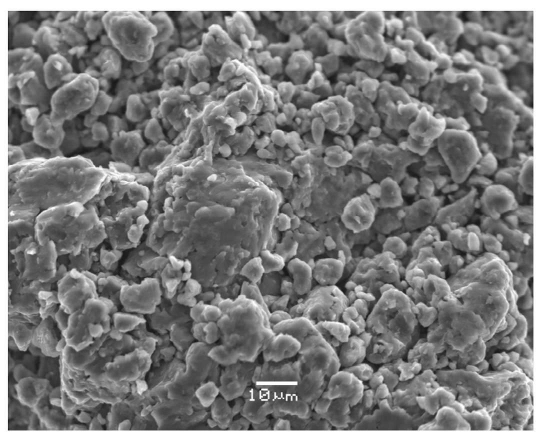
The formation of metastable phase Al_3Mg in the Al-Mg-C system during mechanical alloying

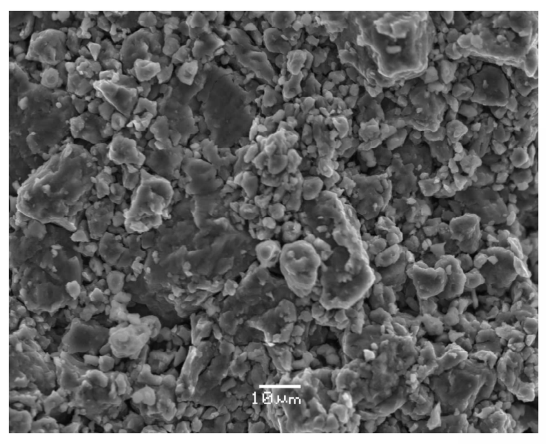
I.M. Kirian, A.M. Lakhnik, A.D. Rud
G. V. Kurdyumov Institute for Metal Physics of the N.A.S. of Ukraine
UA-03142 Kyiv, Ukraine
kiryan.inna@gmail.com



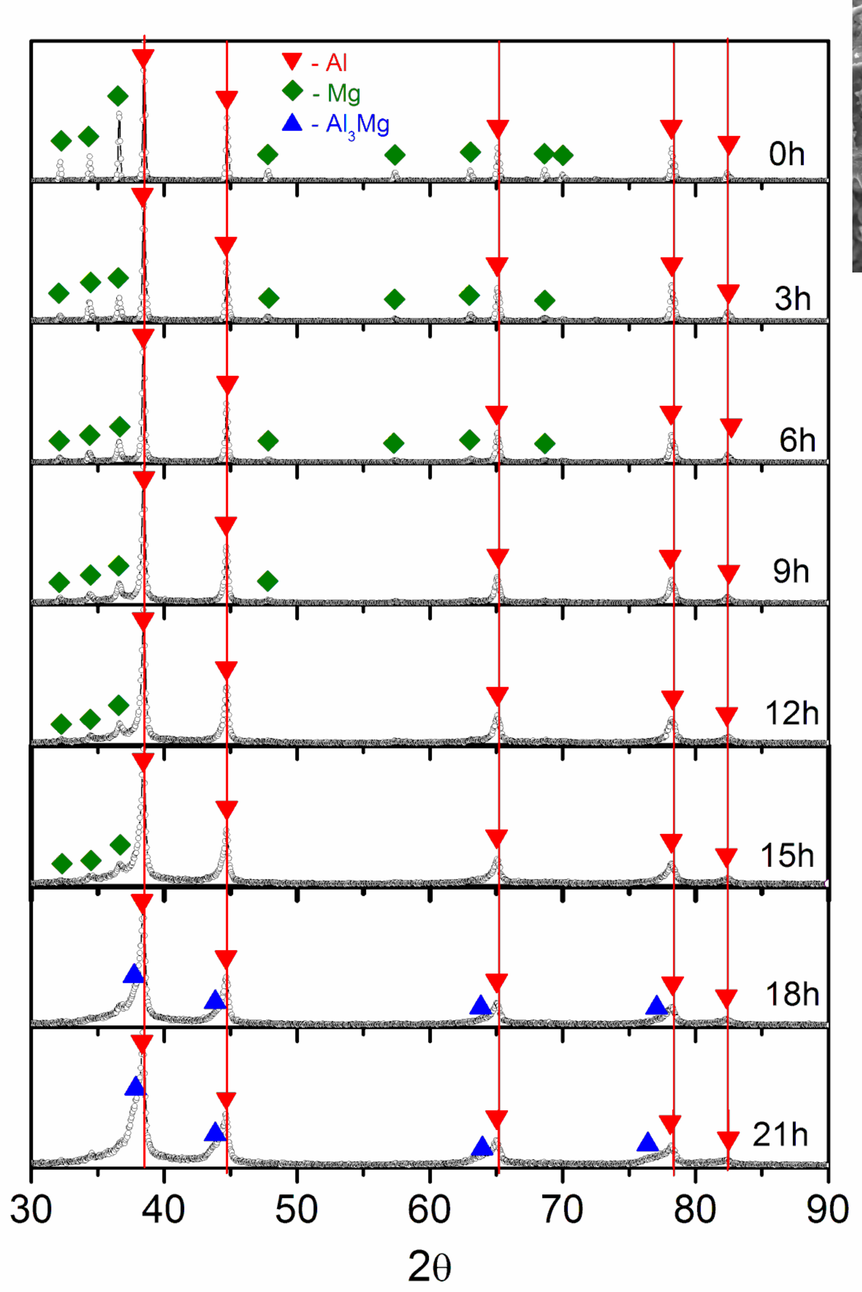


The Al-Mg, Al-Mg-C, and Al(Sc)-Mg-C powders were prepared through the solid state mechanical alloying (MA) by ball milling. The MA process was carried out in the planetary mill in argon gas atmosphere. The phase evolution dynamics during milling for various times was characterized in details by the XRD analysis technique. Phase composition and structure parameters of the powders were investigated by the Rietveld refinement method. It was found the solid state process control agent (PCA) (carbon) and alloying Al by Sc accelerates metastable intermetallic phase formation under MA.





XRD pattern of mechanically milled binary $Al_{75}Mg_{25}$ powder mixture



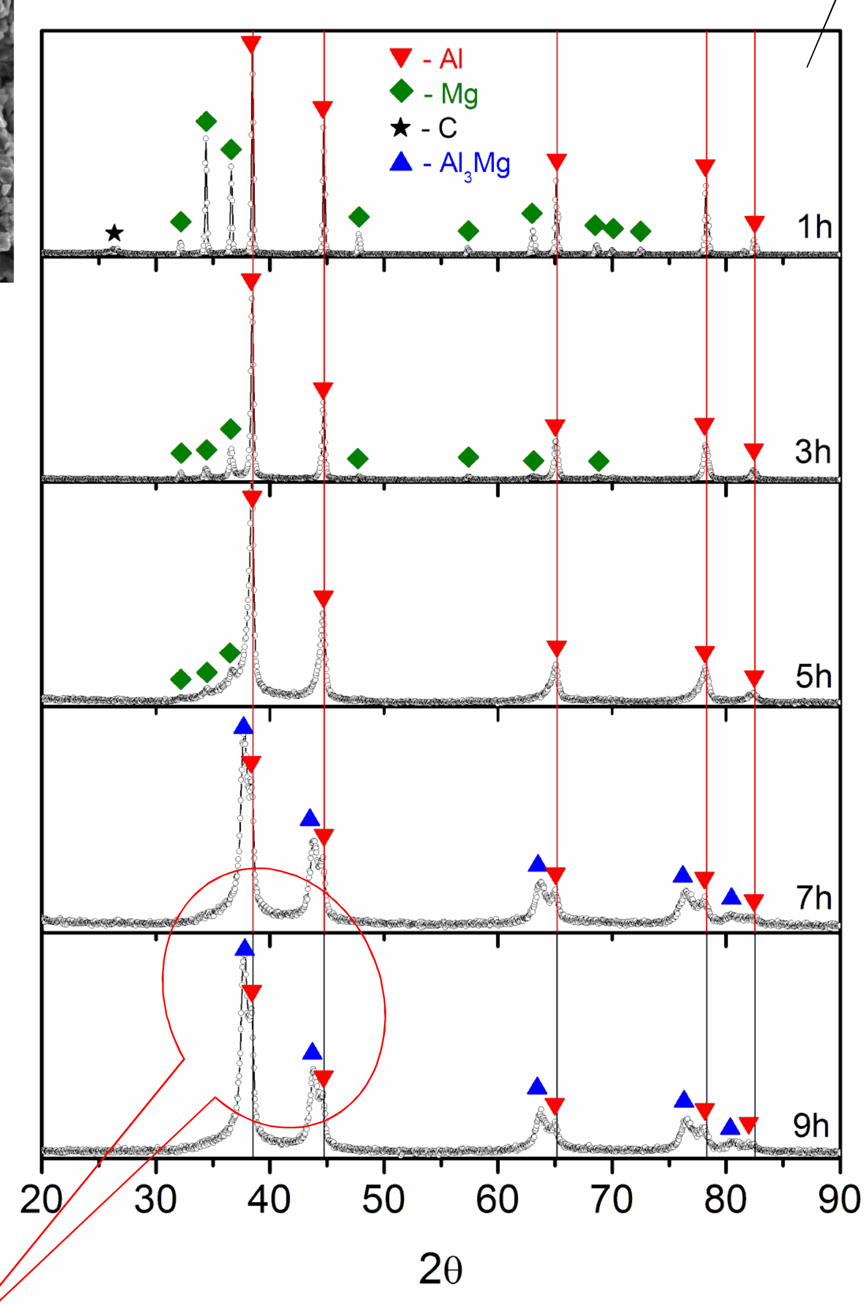
The red vertical lines correspond to the position of the diffraction maxima for pure aluminum.

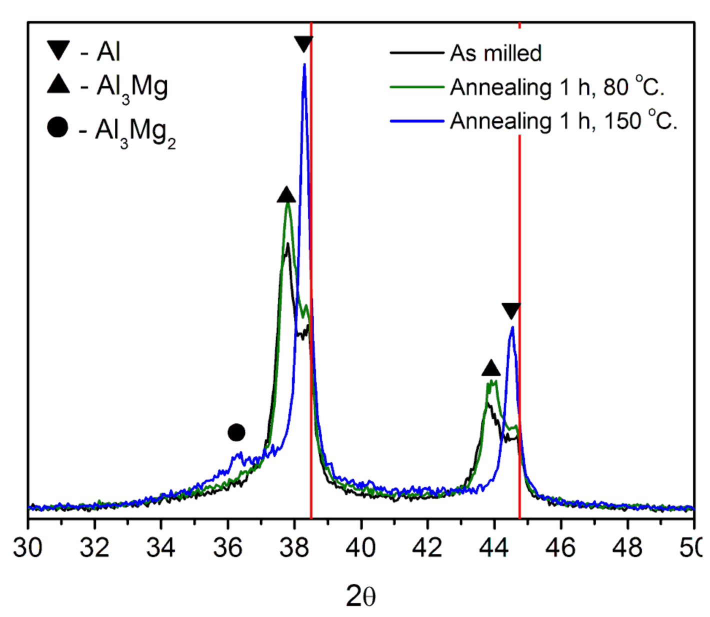
The aluminum powder sawdust and the aluminum-scandium ligature powder filings have been produced from the ingots by the hand rasping. The powder blends $y[\{xAl(100\text{-}x)Sc\}_aMg_b]+(100\text{-}y)C$ (x = 100, 99.7 and 98 wt%; a =75 at%, b = 25 at%; y = 95 and 100 wt%.) used in this study were fabricated via the mechanical alloying. In our experiments the Al powder, pre-alloyed Al(Sc) powder and Mg powder were weighed to keep the quantity of aluminum and magnesium to a constant ratio of 3 : 1 for all mixtures. A total of the four powder blends have been prepared to ball milling:

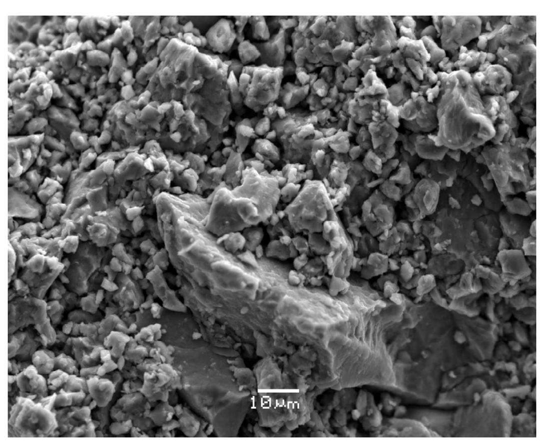
- binary Al75Mg25 powder mixture;
- the ternary powder mixture 95 wt%[$Al_{75}Mg_{25}$] + 5wt% C;
- four-component powder mixture 95 wt%[$Al(+0.3\ wt\%Sc)_{75}Mg_{25}$] + 5wt% C;
- four-component powder mixture 95 wt%[$Al(+2\ wt\%Sc)_{75}Mg_{25}$] + 5wt% C.

The laboratory planetary mill (Fritsch Pulverisette 6) was employed to conduct the ball milling experiments. The ball milling of the powder mixtures performed in a home-made stainless steel milling vial equipped by pressure transducer and valve. Before milling the vial has been evacuated by a forevacuum pump and then filled by the inert gas. The sample weight, the rotational speed of the vial (400 rpm), the amount of the steel balls (20 mm; 15) and the ball-to-powder ratio (15:1) were kept constantly in the all experiments. X-ray powder diffraction technique has been used to characterize the phase composition and structure parameters. X-ray diffraction patterns were recorded with a powder diffractometer (HZG-4A) in the Bragg-Brentano geometry using Cu Kα radiation. Data were collected in the 2θ range 10° to 100° with a step interval of 0.05° and a count time 5 sec per step.

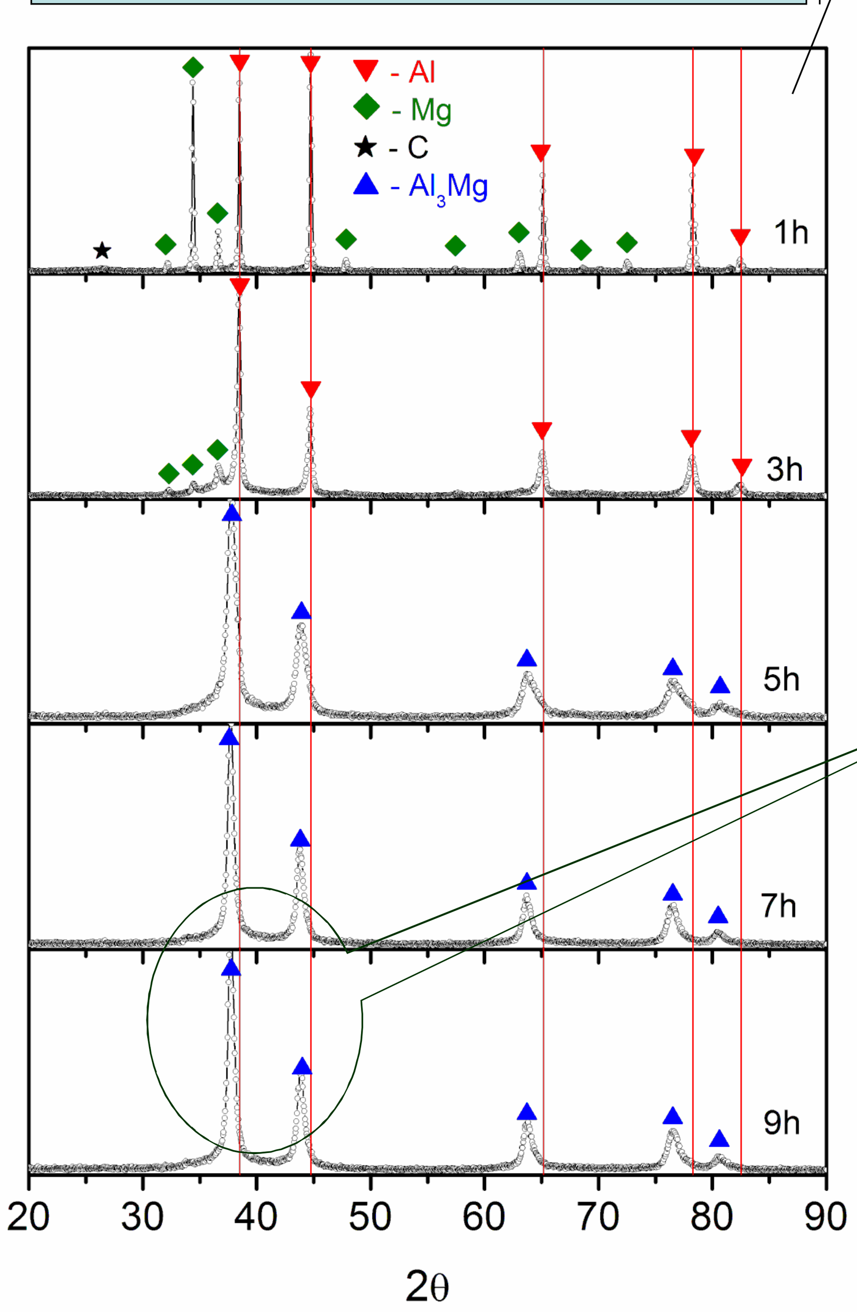
XRD pattern of mechanically milled ternary powder mixture 95 wt%[$Al_{75}Mg_{25}$] + 5wt% C.

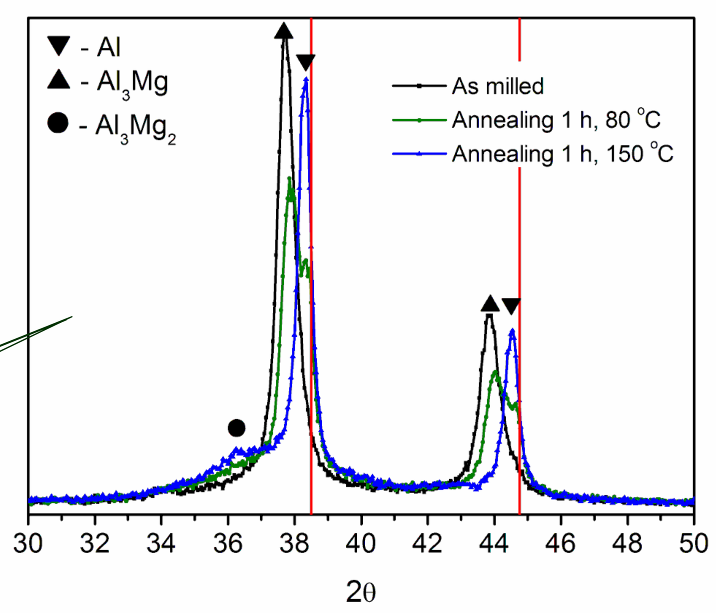


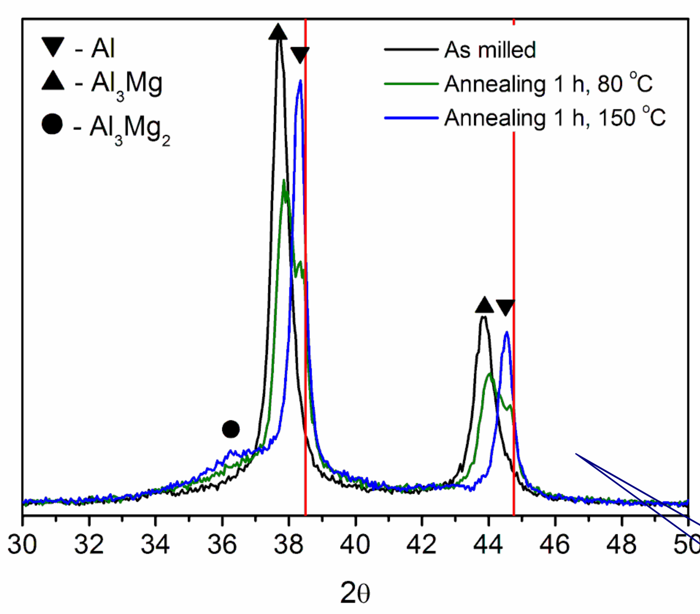




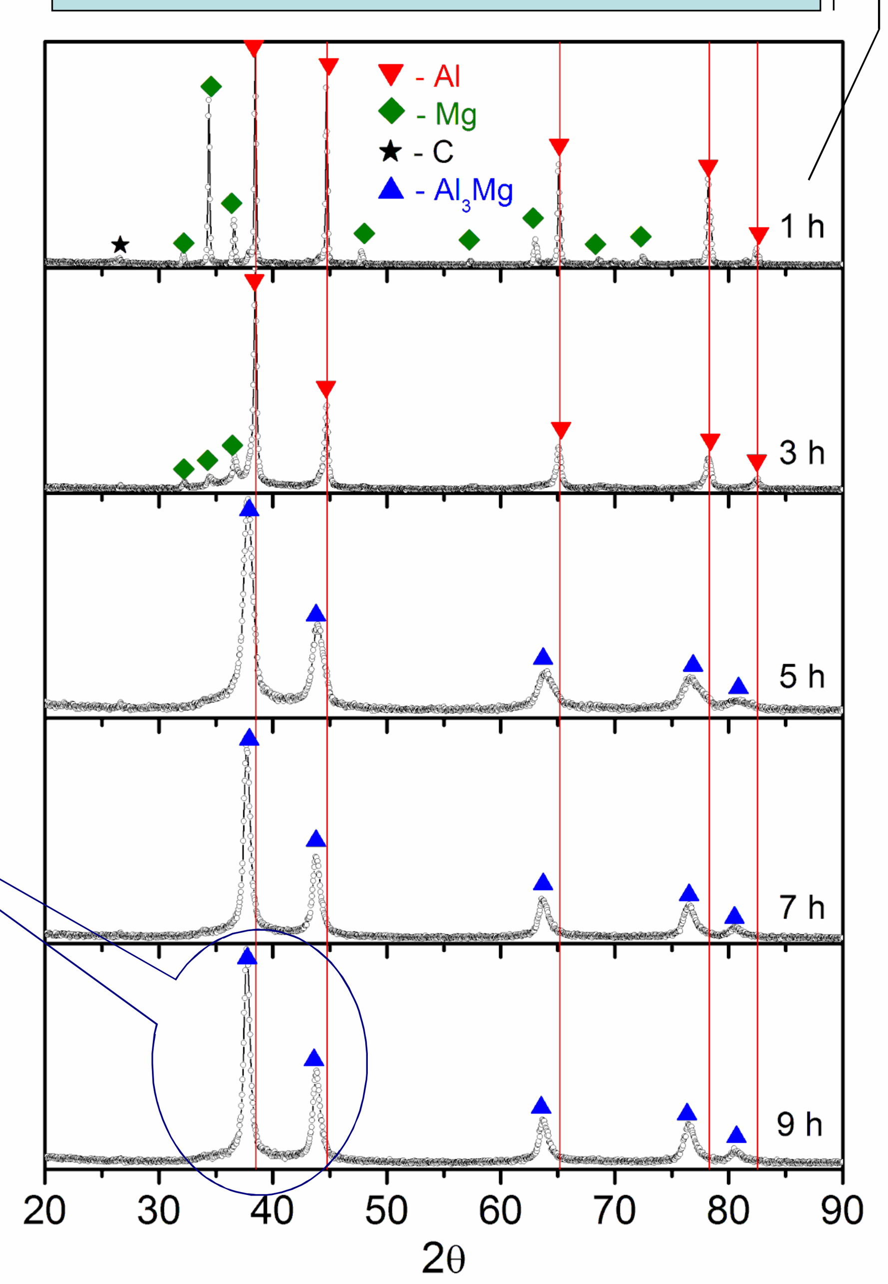
XRD pattern of mechanically milled four-component powder mixture 95 wt%[$Al(+0.3\ wt\%Sc)_{75}Mg_{25}$] + 5wt% C.







XRD pattern of mechanically milled four-component powder mixture 95 wt%[$Al(+2\ wt\%Sc)_{75}Mg_{25}$] + 5wt% C.



1. It was found the β″ metastable intermetallic Al_3Mg $L1_2$ phase is formed during the ball milling of the Al-Mg powder mixtures.
2. It was shown the process control agent (PCA) (carbon) greatly raises powders reactivity and accelerates interaction between Al and Mg under mechanical alloying.
3. The alloying of aluminum with scandium and the use of carbon as a PCA promote the formation of intermetallic compounds, including the metastable Al_3Mg.
4. A synergistic effect due to the simultaneous use of doping by transition elements (scandium) and carbon as a PCA takes place. Eeven the minimum content of scandium in Al (0.3 %wt.) essentially accelerates the formation of intermetallic compounds under MA.