SYNTHESIS OF IN-SITU QUASICRYSTALLINE AL-MATRIX COMPOSITE

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Introduction

The composite materials are entering their second century of development if the year 1942 is considered as the landmark. In this year the US Rubber Co. developed their first glass fiber reinforced polyester composite. Since then the demand and consumption of composite materials grows every year. Composites are made as a combination of usually very different materials, which are put together, i.e. metal and glass, metal and ceramic, carbon and carbon etc. In recent years there is increased scientific interest in fabricating composite materials that contain quasicrystalline phases (QC) in one form or another. Considerable efforts were made to study the deformation processes in QC phases [1], which are confined to Al-Cu-Fe and Al-Mn-Pd alloys. In past ten years studies of mostly mechanically alloyed and cast composite materials came to light [2-4], where all these composites could easily be designated as *ex-situ* composites. The fabrication of *ex-situ* and *in-situ* composites are processes that differ from each other where ex-situ composites usually suffer from defects such as porosity and insufficient adhesion between reinforcing component and matrix material. The *in-situ* composites are usually free of such defects because the reinforcing component forms and grows from within using the matrix material as a substrate to grow on and from. This is very often with metal matrix composites where the fabrication process involves the synthesis of the composite beginning with the melt. Provided the chemical composition and the cooling rates are favorable the QC phases will form and grow in such systems. The QC phases can appear as primary crystallized phase and/or as a phase within binary or ternary structures [5]. In our paper the Al-Mn-Be alloys with additions of Cu were synthesized using standard vacuum-induction melting under Ar. These alloys were than cast applying three different cooling rates in order to explore the possibilities of fabrication metal matrix composites reinforced with suitably sized QC particles by means of reliable and cost effective process techniques (e.g. casting).

Experimental

Alloys were synthesized from pure Al, Cu, Mn and AlB5 master alloy using vacuum-induction melting under Ar followed by casting into permanent metallic mould. Synthesized alloys were than remelted and cast using: melt-spinning technique, casting into copper mould and continuous casting. Specimens for the LOM, SEM, XRD, TOF SIMS and TEM investigations were prepared from all alloys cast with the all three techniques. The TEM specimens for the JEOL 2000 FX, specimens were prepared using the ion beam etching and polishing system GATAN PIPS 691 (3 keV, angle ±2.5º). X-ray diffraction (XRD) was carried out at XRD1 beamline (Elettra, Sincrotrone Trieste, Italy) using synchrotron X-rays with a wavelength of 0.1 nm in a transmission mode.

Results and Discussion

In the case of the Al-Mn-Be alloys (AlMn10Be4 and AlMn5Be4) the QC phases formed during melt spinning (Fig. 1) as primary phase and within the binary structure.

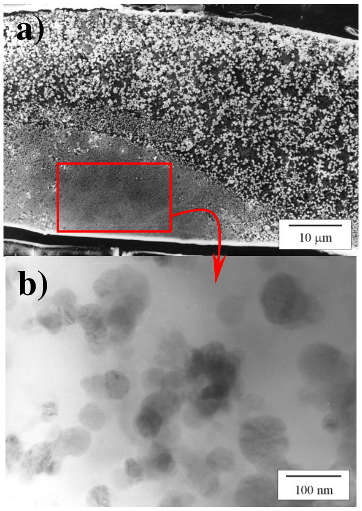

Fig. 1 a) SEM-micrograph of a melt-spun ribbon from the Al-Mn-Be alloy, b) TEM-micrograph of QC particles from the featureless zone at the wheel surface

The mean size of QC particles ranges from ~5 nm on the contact surface up to few tens of nanometers on the free surface is of order of few hundreds of nanometers. Constitution changed when copper is added to the Al-

Mn-Be alloy and casting into copper mould is employed (Fig. 2).

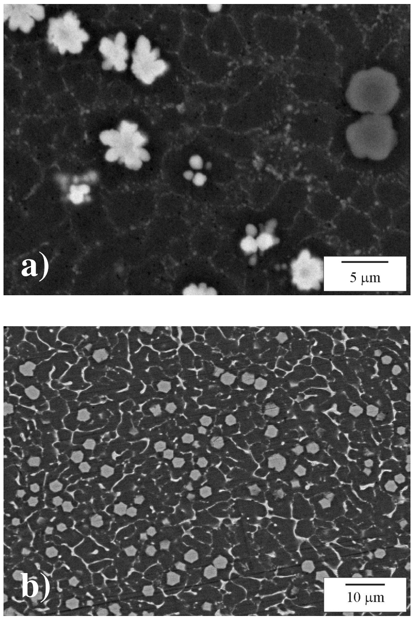

Fig. 2 SEM-micrographs of die-cast a) Al-Mn-Be alloy and b) Al-Mn-Be-Cu alloy

QC particles are smaller and more uniform in size and evenly distributed, Fig. 2b. Preliminary compression test of Al-Mn-Be-Cu alloys revealed presence of typical shear bands (Fig. 3a).

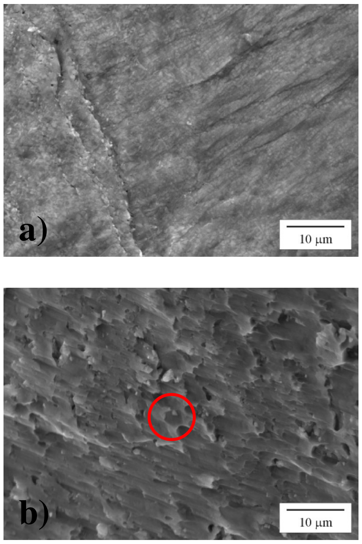

Fig. 3 The outer surface of the specimen (rod) a) and fracture surface b), both after compression test. Red circle denotes the area where the QC particle was embedded

The fracture has ductile character with QC particles being torn out of the matrix (Fig. 3b, red circle). Toughening reaches plateau just below 500 Nmm^{-2} and remained constant for all three specimens. The ϕ 8 mm rod exhibits sharp drop in stress at $\varepsilon = 0.35$ due to the specimen fracturing during the test. The stress-deformation curves are otherwise similar to curves typical for the *hcp* metals and alloys.

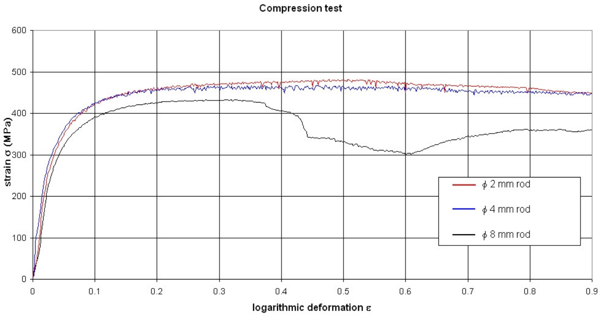

Fig. 4 Stress vs. deformation for Al-Mn-Be-Cu alloy rods during compression test with $\dot{\varepsilon} = 0.001$

Conclusions

The Al-Mn-Be alloys with additions of Cu are prone to form QC phases even when different fabrication techniques are employed with diverse cooling rates. The size of QC particles varies from few nanometers up to few micrometers depending both on chemical composition and the cooling rate. The toughening during the compression test indicates that the macro response of the QC reinforced composite is similar to that of the *hcp* metals and alloys.

Reference

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