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Rapid Communication

Deformation, decomposition and hardening behavior of nano Al7075 alloy prepared by mechanical milling and hot pressing

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ABSTRACT

Al–Zn–Mg–Cu alloy with different crystallite size is prepared by mechanical milling and high temperature consolidation. X-ray line profile analysis and HRTEM image show high temperature consolidation results in insignificant grain coarsening. Microhardness of the alloy as a function of crystallite size shows break down of Hall–Petch relationship.

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1. Introduction

At present, severe plastic deformation (SPD) [1] and mechanical milling [2] are two common methods of nano crystallization to improve the mechanical property of materials including light weight structural Al7075 alloy. In comparison, mechanical milling has the advantage of reducing the average grain size below 100 nm which is difficult to achieve by SPD [1]. However, the consolidation of the milled powder is always a matter of concern. Conventional cold compaction and sintering can result in significant grain coarsening. Hot pressing can be an alternate and effective process of consolidation. In hot pressing, compaction was carried out by applying pressure at a temperature higher than room temperature but lower than melting point. Pressure at higher temperature facilitates better interparticle binding. However, at higher temperature grain coarsening may occur. Therefore, the primary challenge is to avoid significant grain growth.

Additionally, milling generates different types of defects like dislocation and stacking fault in the material. These types of defects and ultrafine grain influence the precipitation behavior and mechanical properties significantly. Considering all these facts, the objectives of the present study are to (i) produce nanostructured Al7075 alloy by mechanical milling followed by high temperature consolidation (without significant grain growth), (ii) study the hardening behavior, (iii) determine crystallite size, precise lattice parameter and generated defects (dislocation and stacking fault) precisely by X-ray diffraction and transmission electron microscopy technique and (iv) to assess the precipitation behavior of the consolidated alloy.

2. Experimental procedures

Al7075 alloy (Valimet, Inc. USA, 99.7% purity and particle size = 45 μm) was mechanically milled in a Retsch PM-400 planetary ball mill at 300 rpm in toluene for different duration of 5 h, 10 h, 20 h and 40 h. The milled powders were compacted at 400 °C by applying a pressure of 500 MPa (for 1 h). The compaction was carried out in a hardened steel die of 10 mm diameter. Boron nitride was used on the die and punch surface prior to compaction to reduce wall frictional effects.

Microhardness of consolidated alloy was measured using a Vickers' microhardness tester (MMT-X7B, Matsuzawa, Japan). The samples were indented at ten or more different locations with an applied load of 25 gf and the average value is reported.

Microstructural investigation of selected consolidated compacts was carried out by high resolution transmission electron microscope (HRTEM, JEOL 3010, Japan) operated at an acceleration voltage of 200 kV. Samples were cut just below the surface of the

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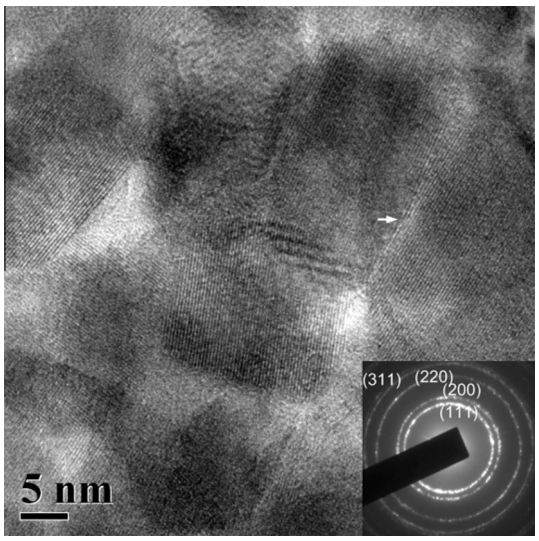

Fig. 1. High resolution TEM image of consolidated compact of 20 h milled powder.

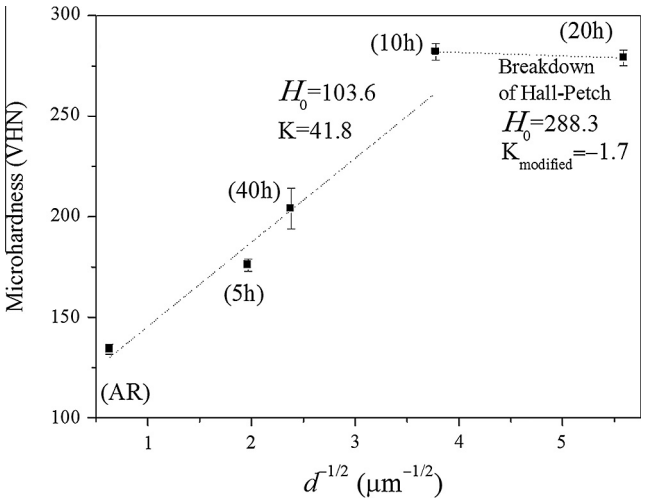

Fig. 3. Vickers microhardness of the consolidated alloy as a function of $d^{-1/2}$.

compacts by a diamond cutter and then polished to a thickness below 100 μm. Circular discs of 3 mm diameter were cut from the polished samples using a Gatan punch. Finally, the discs were thinned to electron transparency by argon ion milling for about 30 min using a GATAN precision ion mill.

X-ray diffraction analysis of the milled alloy and consolidated samples was carried out using an X-ray diffractometer (Philips Panalytical X'Pert Pro) with Cu Kα radiation (wavelength = 0.1542 nm). The measured diffraction patterns were analysed by the Profile Fit software attached with the Philips Panalytical X'Pert High Score Plus software (using pseudo-Voigt function with $aK\alpha_2/K\alpha_1$ intensity ratio of 0.5) for the determination of the diffraction-line positions. Lattice parameter (a) of the powder and consolidated alloy was calculated for each reflection. The precise lattice parameter (a_p) was determined by suitable extrapolation of the variation of lattice parameter as a function of the Nelson–Riley (N–R) parameter ($\cos^2\theta/\sin\theta + \cos^2\theta/\theta$).

Average grain size and dislocation density were determined by employing Convolution Multiple Whole Profile fitting method

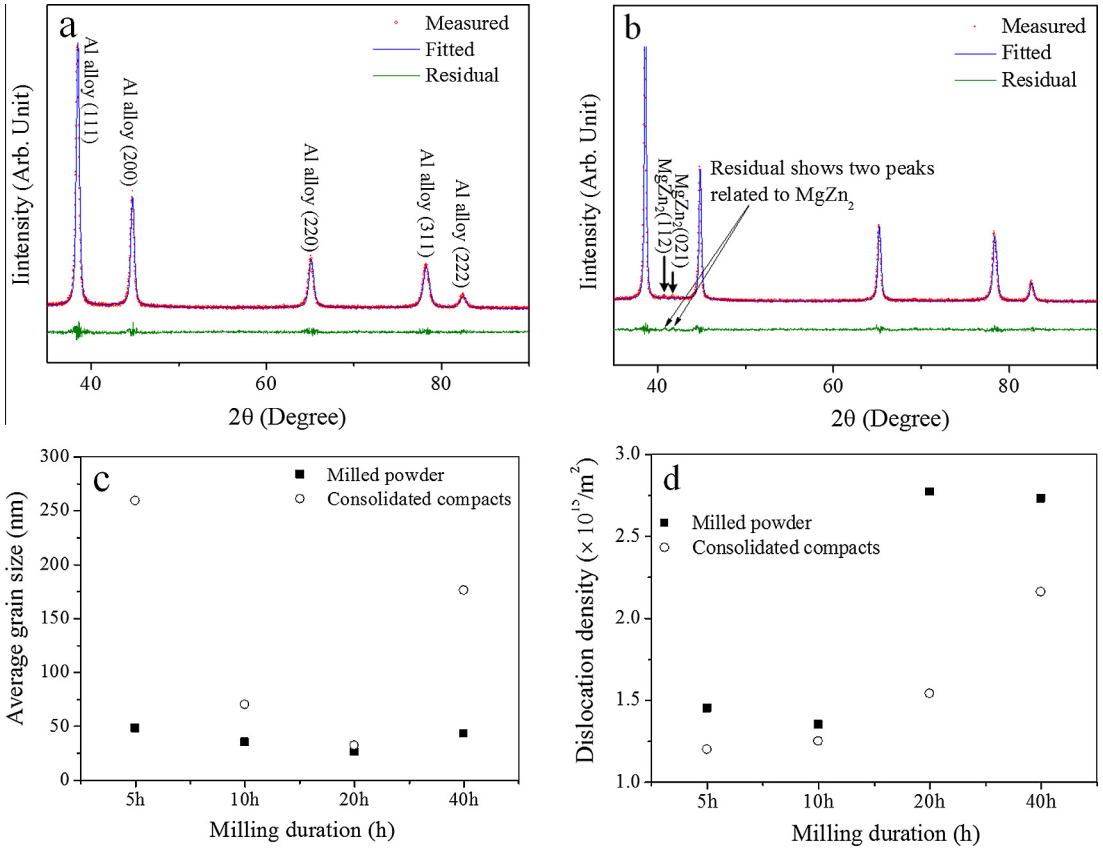

Fig. 2. The measured (open circles) and fitted (solid lines) diffraction profiles of the (a) 10 h milled alloy powder and (b) consolidated compact of similar powder. (c) Grain size and (d) dislocation density of the powder alloy and corresponding consolidated compacts as a function of milling time.

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