Experimental Report

Proposal: **1-01-130** **Council:** 10/2012

Title: Application of neutron powder diffraction to the characterization of impulse atomized Al-Cu-Sc droplets

This proposal is a new proposal

Researh Area: Materials

Main proposer: **REINHART Guillaume**

Experimental Team: NGUYEN-THI HENRI
REINHART Guillaume
SARKIS Carole
SALLOUM ABOU JAOUDE Georges

Local Contact: HANSEN Thomas

Samples: Al-4wt%Cu with addition of Scandium (0, 0.1, 0.2, 0.4 wt%)

Instrument	Req. Days	All. Days	From	To
D20	2	2	26/03/2013	28/03/2013

Abstract:

The development of aluminium alloys with increased strength and ductility is an ongoing challenge for automotive and aerospace applications. The addition of Scandium (Sc) has yielded improved grain refinenent in binary aluminium alloys, as well as in complex alloys. Although Sc is an expensive alloying element when compared to industrially established Ti/B grain refiners, its combination with rapid solidification holds promise to capture the benefits of Sc grain refining with minimal additions.

The aim of this proposal is to obtain experimental information on the solidification path of Impulse Atomized (IA) droplets of Al-Cu and Al-Cu-Sc alloys.

It has been shown that high resolution neutron powder diffraction is a method of choice to determine the solidification of rapidly solidified droplets and perform relevant comparison with numerical models.

The advanced characterization of IA droplets of aluminium alloys with and without addition of Sc can thus provide precise benchmark data to be used in numerical simulations, enlightening the effect of Sc on the solidification conditions.

Introduction

The development of aluminium alloys with increased strength and ductility is an ongoing challenge for automotive and aerospace applications. These improved properties are achievable through increased refinement of the microstructure, i.e., higher cooling rates (rapid solidification), as well as through the addition of alloying elements. The addition of Scandium (Sc) has yielded improved grain refinenent in binary aluminium alloys, as well as in complex alloys [1]. Although Sc is an expensive alloying element when compared to industrially established Ti/B grain refiners, its combination with rapid solidification holds promise to capture the benefits of Sc grain refining with minimal additions. Therefore, reference experiments are needed in order to validate numerical simulations and ultimately optimize solidification processes.

Impulse Atomization (IA) is a rapid solidification process developed at the University of Alberta (Canada) in the Advanced Materials and Processing Laboratory (AMPL-UofA) [2]. In this technique a molten metal is pushed through several orifices by applying recurring forces, forming liquid jets of finite length in the atomization chamber. The liquid jets break into small droplets due to Raleigh instability and solidify while falling through the gas atmosphere. The specific solidification conditions of droplets obtained by IA make it a model system for the study of equiaxed solidification [3]. The advanced characterization of IA droplets of aluminium alloys with and without addition of Sc can thus provide precise benchmark data to be used in numerical simulations, enlightening the effect of Sc on the solidification path.

The aim of this experiment is to obtain experimental information on the solidification of IA droplets of Al-Cu and Al-Cu-Sc alloys by using high resolution neutron powder diffraction diffraction which is a method of choice to determine the solidification path of rapidly solidified droplets and perform relevant comparison with numerical models [4-5]

Experimental details

The nominal composition of the powders was Al-4.5wt%Cu with different amounts of Sc (0, 0.1, 0.2 and 0.4 wt%), diameter ranges (< 212, 212-255, 255-300, 300-350, >350 μm), and after annealing after various time. A wavelength λ = 1.36 Å and a takeoff of 118 degrees were used to ensure the detection of small lattice parameter variations as well as intermetallic compounds.

The sample were sent from Canada in a box containing dry ice (carbon dioxide) to maintain the samples at a cold temperature (< 4°C) and thus limit the formation of Al_2Cu intermetallic phase during transportation. During the experiment, the sample were encapsulated into cylindrical vanadium cans and kept cold with ice cube. They were removed from the storage box just before being put in the neutron beam to record powder diffraction diagrams. In total 33 of 46 samples could be investigated during the 2 days of allocated beamtime.

First analyses

The primary phase that forms during rapid solidification is usually supersaturated with solute. According to the Al-Cu equilibrium phase diagram, copper is soluble in aluminum to about 5.6 wt% at 550°C. The incorporation of solute changes the average lattice spacing of the primary phase and it has been shown that the effective lattice parameter of aluminum decreases as copper concentration increases [6]. Figure 1a shows the position of the (422) peak for two sets of Al-4.5wt%Cu droplets, without and with annealing at 300°C for 20 hours. The peak position is shifted to the left for the annealed droplets which corresponds to a decrease of the lattice parameter. This variation can be attributed to a decrease in copper concentration of the aluminum phase and is in agreement with recent electron micro-probe analysis performed at the University of Alberta. A smaller lattice parameter is also observed for droplets of the same size but with addition of scandium (Figure 1b), along with the formation of phases that have not been identified so far. This change could be attributed to the different solidification path induced by the addition of scandium. Further works will aim to perform Rietveld refinement of the powder diagrams to precisely measure the lattice parameter variations and the evolution of the Al and Al_2Cu phase fraction as a function of the droplet size and nominal composition.

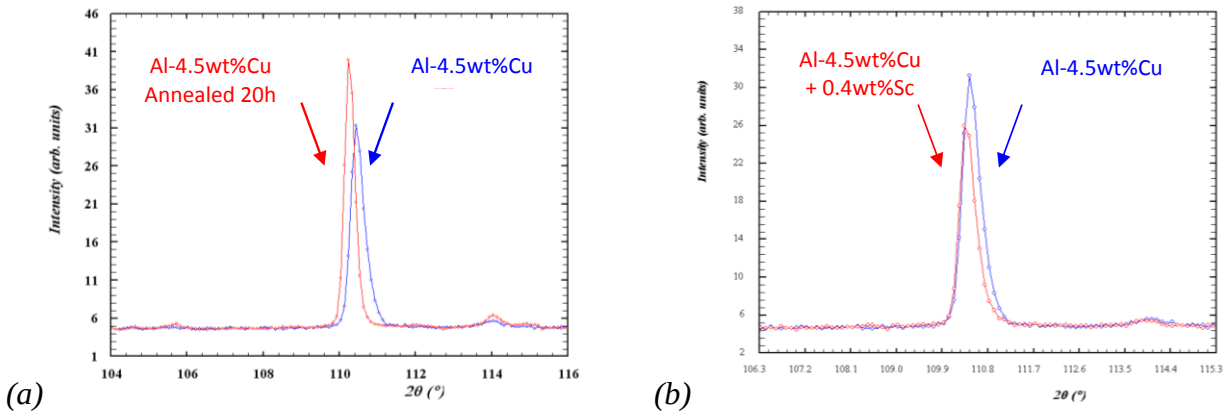

Figure 1: Positions of the (422) peak of the aluminum phase for Al-4.5wt%Cu droplets (a) with and without annealing and (b) with and without addition of Scandium.

References

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[6] V.A. Lubarda, Mechanics of Materials 35 (2003) 53-68