| | | |
|---|---|---|
| ESRF | Experiment title:<br>**Characterization of equiaxed growth in Al – Cu alloys by synchrotron X-ray radiography.** | **Experiment number**:<br>IN-727 |
| **Beamline**:<br>ID19 | **Date of experiment**:<br>from: 21/04/2010 to: 22/04/2010 | **Date of report**:<br>21/07/2010 |
| **Shifts:**<br>3 | **Local contact(s)**:<br>Paul Tafforeau | *Received at ESRF:* |


**Names and affiliations of applicants** (* indicates experimentalists):

*NGUYEN-THI Henri*, REINHART Guillaume*, BOGNO Aziz**, IM2NP UMR CNRS 6242, Campus Saint-Jérôme, Case 142, 13397 Marseille Cedex 20, France

*SCHENK Thomas**, LPM, Ecole des Mines de Nancy, Parc de Saurupt, 54042 Nancy cedex, France

*BOLLER Elodie, BARUCHEL José, GUICHARD Xavier* (ESRF)


According to an email from Mrs. K. Fletcher, it seems that we do not have to write a report for this experimental session. However, we take this opportunity to give you a list of recent references of papers published during the past 18 months as a result of experiments done at the ESRF on this topic.

**Publications**


**[1]** *Buffet A., Nguyen-Thi H., Bogno A., Schenck T., Mangelinck-Noël N., Reinhart G., Bergeon N., Billia B., Baruchel J.*
*Measurement of Solute Profiles by Means of Synchrotron X-Ray Radiography during Directional Solidification of Al – 4 wt% Cu alloys*
*Materials Science Forum 649 (2010) 331-336*

***Abstract:*** *In the present study, we report on an image analysis procedure, which enables to extract from synchrotron radiographs the long range solute profiles in the whole sample and in both phases (solid and liquid). This image analysis is based on the measurement of local density differences, and is applied to study the directional solidification of Al - 4wt% Cu alloy, from planar to onset of the initial instability. Dedicated experiments were carried out at the European Synchrotron Radiation Facility (ESRF) in Grenoble (France). In order to validate this analysis the value of a key solidification parameter, namely the partition coefficient, was experimentally determined during the planar solidification, and a very good agreement was found with value found usually in the literature. On a further step, the evolution of the microstructure and solute profile during the initial transient of solidification was analysed in detail.*

**[2]** *Bogno A., Nguyen-Thi H., Bergeon N., Mangelinck-Noël N., Schenck T., Billia B., Boller E., Baruchel J.*
*Application of Synchrotron X-Ray Radiography to the Study of Dendritic Equiaxed Microstructure Formation in Al – Cu alloys*
*Nuclear Instruments and Methods in Physics Research B 268 (2010) 394–398*

***Abstract:*** *The phenomena involved during equiaxed growth, which is the most common growth morphology in metal casting, are dynamic. Therefore, in situ investigation is necessary to fully analyse the microstructure formation. Synchrotron X-ray radiography has become a major tool for in situ characterization of solidification in metallic systems. This paper reports on dedicated equiaxed solidification experiments carried out at the European Synchrotron Radiation Facility (ESRF) in Grenoble-France on Al–10 wt. % Cu alloy. The analysis is based on the recorded images obtained through absorption radiography. Equiaxed growth is achieved in nearly isothermal conditions and observed continuously*

*in real time from the early stages of solidification to the final state. The evolution of the dendrite arm lengths and the corresponding growth rates are analysed for two couples of grains in relation with their environment. This analysis suggests that the solutal interaction is dominant between equiaxed grains.*

**[3]** *Bogno A., Nguyen-Thi H., Billia B., Bergeon N., Mangelinck-Noël N., Boller E., Schenk T., Baruchel J.*
*In situ analysis of dendritic equiaxed microstructure formation in Al-Cu alloys by synchrotron X-ray radiography*
*Trans. Indian Inst. Met. 62, n° 4-5 (2009) 427-431*

***Abstract*****:** *This paper reports on experiments dedicated to equiaxed solidification carried out on Al – 10 wt% Cu alloy at the European Synchrotron Radiation Facility (ESRF) in Grenoble-France. Equiaxed growth was achieved in nearly isothermal conditions and observed continuously in real time from the early stages of solidification to the developed grain structure by X – ray radiography. The length of primary dendrite arms was measured on several growing equiaxed grains as a function of time and it was found that dendrite arm evolution can be well fitted by the Kolmogorov - Johnson - Mehl - Avrami (KJMA) function. The growth of four primary dendrite arms of a single grain was then characterized. The dendrite arms behaved differently depending on their growth directions and the presence of grains in their vicinities. At the beginning, the dendrite arm directed upwards was growing faster than the ones growing below because of "self - poisoning" due to gravity driven fluid flow. In the late stage of solidification, analysis on several couples of grains growing towards each other confirmed that solutal interaction was the main cause of growth being stopped.*

**[4]** *Yun Chen, Abdoul-Aziz Bogno, Bernard Billia, Xiu Hong Kang, Henri Nguyen-Thi, Dian Zhong Li, Xing Hong Luo and Jean-Marc Debierre.*
*Phase-field modeling of the initial transient in directional solidification of Al – 4 wt% Cu alloy*
*ISIJ international (accepted)*

***Abstract:*** *The initial transient in directional solidification of Al – 4 wt% Cu alloy by cooling-down is investigated by numerical simulation using the phase-field model proposed by Karma (Phys. Rev. Lett., **87**(2001) 115701), which includes solute antitrapping in mass conservation relation and is solved by the adaptive finite element method. The simulated velocity of the unsteady planar solidification interface and the solute profile in the liquid are always close to the predictions of the Warren-Langer analytical model of initial solidification transient (Phys. Rev. E, **47**(1993) 2702.) but only in the very beginning of growth in fair quantitative agreement with the experimental data obtained by means of in situ and real-time X-ray radiography at the European Synchrotron Radiation Facility (ESRF). Then, the influence of gravity-driven fluid flow becomes significant in experiments, and increases with time. In the phase-field simulations, once the smooth solidification front has lost morphological stability in the initial solidification transient, the evolution of the non-planar solid-liquid interface microstructure varies with the processing control parameters. It is found that the solid-liquid interface shape changes through transitions from flat to cellular, cellular to dendritic, cellular or dendritic to seaweed depending on the values of the applied cooling rate and temperature gradient.*

**[5]** *Billia B., Nguyen-Thi H., Mangelinck-Noël N., Bergeon N. Jung H., Reinhart G., Bogno A., Buffet A., Hartwig J., Baruchel J., and Schenk T.*
*In Situ Synchrotron X-Ray Characterization of Microstructure Formation in Solidification Processing of Al-based Metallic Alloys*
*ISIJ international (accepted)*

***Abstract:*** *The microstructure formed during the solidification step has a major influence on the properties of materials processed by major techniques (casting, welding …). In situ and real-time characterization by synchrotron X-ray imaging is the method of choice to unveil the dynamical formation of the solidification microstructure in metallic alloys, and thus provide precise data for the critical validation of the theoretical predictions of that is needed for sound advancement of modeling and numerical simulation. After a description of the experimental procedure used at the European Synchrotron Radiation Facility (ESRF), dynamical phenomena in the formation of the grain structure and dendritic or equiaxed solidification microstructure in Al-based alloys are presented. Beyond fluid flow interaction, earth gravity induces stresses, deformation and fragmentation in the dendritic mush. Settling of dendrite arms and equiaxed grains thus occurs, in particular in the columnar to equiaxed transition. Other types of stresses and strains are caused by the mere formation of the solidification microstructure itself. In white-beam X-ray topography, stresses and strains are manifested by specific contrasts and breaking of the Laue images into several pieces. Finally, quantitative analysis of the grey level in radiographs enables the analysis of solute segregation, which noticeably results in solutal poisoning of growth when equiaxed grains are interacting.*