X-Ray Tomoscopy: Exploring temporal resolution

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Summary: Time-resolved in-situ and in-operando tomography is increasingly moving into the focus of materials research. For this purpose we developed real-time in-situ tomography with acquisitions rates of several hundreds of tomograms per second, which we call "tomoscopy" and demonstrate its potential with different case studies such as liquid metal foams or solidifying alloys.

1. INTRODUCTION

For the analysis of dynamic processes temporal resolution is the most important parameter to optimize, but without underrating others such as spatial resolution, field of view and total acquisition time. Recent developments in time-resolved tomography at different synchrotrons are focused on combined spatio-temporal resolution for in-situ and dynamic analyses in the materials science research field. They allow for sub-second acquisition velocities [1-7]. Time-resolved tomography has a long and unsystematic history of nomenclature. Therefore we recently proposed the term tomoscopy for time-resolved tomography in analogy to radioscopy and tps (in analogy to fps) to quantify the number of tomograms per second [8].

2. EXPERIMENTAL METHOD

The sample environment is composed of contactless heating of the X-ray transparent crucible made from boron nitride into which samples are placed. Temperature is measured and controlled using a pyrometer. The X-ray transmission image produced by the sample was converted to visible light using a 150−200-µm thick LuAG:Ce scintillator and magnified by a microscope ranging from about 2x to 4x. This visible light image was then recorded by a high-speed camera resulting in an effective pixel size of 2.5−4.9 µm. The self-developed high-speed rotation stage allowed for an operation at frequencies >100 s^{-1} while maintaining a very precise alignment of the rotation axis (very low eccentricity and wobble) and ensuring accurate time-to-angle stability, allowing for more than 200 tomograms per second. The work was performed at the imaging facility at EDDI beamline, Bessy II, Berlin, Germany as well as at the Tomcat beamline, SLS, Villigen, Switzerland.

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3. RESULTS

We present how tomoscopy can be performed at such speeds and some recent results. First we analyse the growth and evolution of liquid metal foams, where knowledge about the mechanisms of bubble formation, growth and degradation is gained. We analyse the phenomena preceding film rupture and observe a film thinning during the last second before rupture. We also found avalanches of ruptures causing topological rearrangements in a time frame of a few tenths of milliseconds. We studied as well the solidification kinetics of Al-based casting alloys such as AlCu10 for different cooling rates, observing in 3D the evolution of alpha crystals. Solidification has a strong influence on the later microstructure and mechanical properties of the solidified material.

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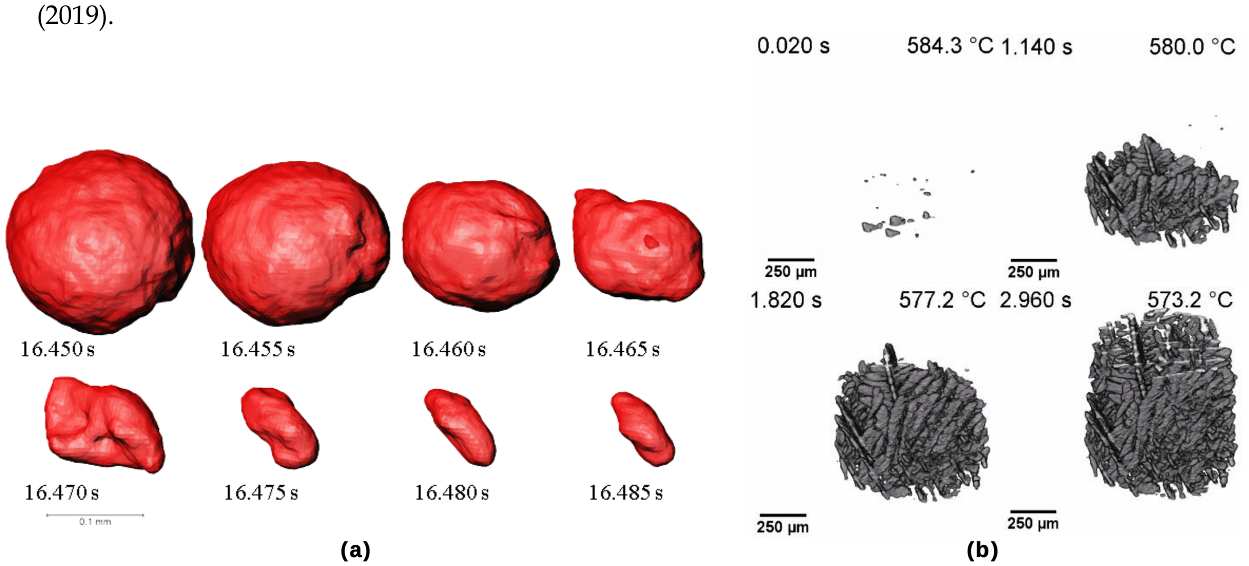

Figure 1: Series of tomograms extracted from a tomoscopic experiment with 200 tps (a) of a collapsing gas bubble in a metallic foam and (b) of a solidifying AlCu10 alloy at a cooling rate of 4 K/s.