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Rapid Solidification in Thin-Film Al-Cu Alloys: Capturing the Dynamics with Time-Resolved In Situ TEM

Joseph T. McKeown[1], Kai Zweiacker[2], Thomas LaGrange[1], Bryan W. Reed[1], Can Liu[2], Jörg M.K. Wiezorek[2], and Geoffrey H. Campbell[1]

[1] Condensed Matter and Materials Division, Lawrence Livermore National Laboratory, Livermore, CA, USA
[2] Department of Mechanical Engineering and Materials Science, University of Pittsburgh, Pittsburgh, PA, USA

Rapid solidification of metals and alloys has been widely recognized as a viable processing route to obtain unique microstructures with potentially advantageous properties that are not obtainable with conventional solidification processes. Previously, the dynamics of rapid solidification in pure Al [1] and Al-Cu alloy [2] thin films were characterized using the dynamic transmission electron microscope (DTEM) in its singleshot, single-image acquisition mode. Recent upgrades to the DTEM instrument enable a single-shot, multiple-image acquisition mode (so-called movie mode) [3], which allows study of microstructural evolution and kinetics in far greater detail. Movie-mode DTEM provides higher data throughput and a reduction in uncertainty and experimental error while following complex, irreversible processes in time.

Here, we present results of in situ DTEM investigations of rapid solidification in thin-film Al-Cu alloys spanning a composition range from Al-3at.%Cu to approximately the eutectic composition (Al-17at.%Cu). Figure 1 shows a time-delay sequence of images recorded as an 80-nm-thick Al-3at.%Cu thin film re-solidifies after pulsed-laser melting. The upper and lower rows of images were recorded from two separate solidification experiments performed with initial delay times of 0 µs and 20 µs, respectively. Each experiment spans 20.4 µs and produces 9 images using a 2.5-µs interframe spacing and a 50-ns electron pulse duration. Figure 2 shows a plot of the time evolution of the melt pool area and solidification front velocity, obtained directly from the time-resolved images of Figure 1. The velocity can be related to the microstructure evolution seen in Figure 1. The solidification front accelerates up to >2 m/s as the alloy film solidifies with a columnar structure. Solidification completes by ~31 µs after pulsed-laser melting. The details of microstructural evolution and solidification kinetics for all alloy compositions investigated will be analyzed and discussed, along with post-mortem ex-situ characterization of the resultant microstructure.

References

[1] A.K. Kulovits *et al*., *Philosophical Magazine Letters* **91** (2011) 287.
[2] J.T. McKeown *et al*., *Acta Materialia* **65** (2014) 56.
[3] T. LaGrange *et al*., *Micron* **43** (2012) 1108.
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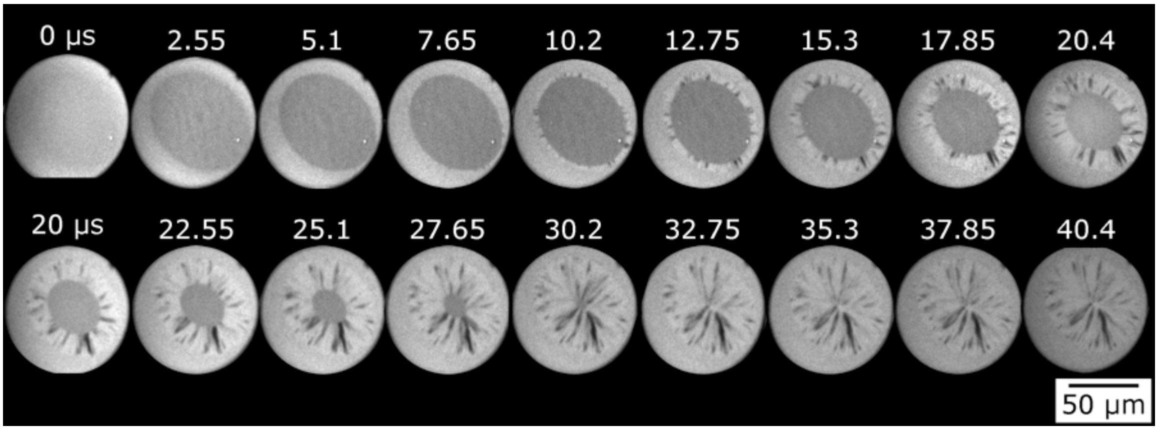

Figure 1. Dynamic time-delay sequence of images recorded as an 80-nm-thick Al-3at.%Cu thin film re-solidifies after pulsed-laser melting. The indicated times above each image are the delays (in μs) between the peak of the Gaussian laser pulse that melted the film and the 50-ns electron pulse used to form the image. The upper and lower rows of images were recorded from two separate solidification experiments performed with initial delay times of 0 μs and 20 μs, respectively. Each experiment spans 20.4 μs.

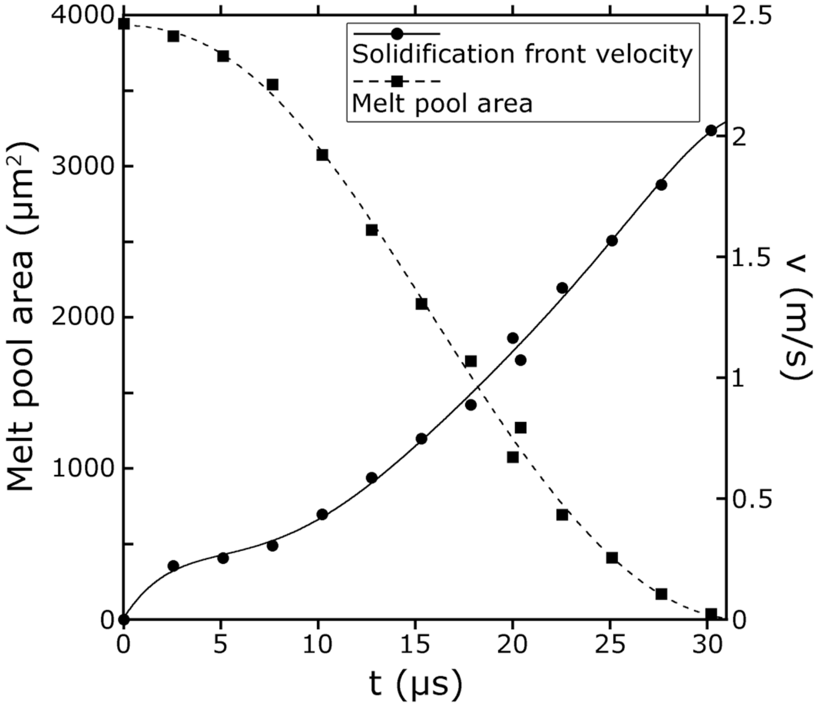

Figure 2. Plot of the melt pool area and solidification front velocity as a function of time, as measured from Figure 1. The plot shows that the solidification front accelerates as the alloy film solidifies.

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