Directional Laser Solidification in Eutectic Al-Cu Thin Films for Nanostructure Self-Assembly

Jerrold A. Floro, Eli Sullivan, Jonathan Skelton, James Fitz-Gerald

University of Virginia, Department of Materials Science and Engineering (22936, Charlottesville, Virginia, USA)

Corresponding author email: floro@virginia.edu

Directional solidification in binary eutectic alloys can lead to self-assembly of two phases as interdigitated bicrystals with a quasi-periodic structure. Periodicities are directly controlled by the solidification speed and can reach the nanoscale. Thin film eutectic alloys are amenable to directional solidification using low-power laser scanning, subject to constraints around agglomeration, heat flow, and evaporation. Eutectic nanostructures are of interest for studying interfacial scattering and anisotropy in energy transport, and as an alternative schema for nanostructured functional materials. In eutectic Al-Cu thin films, highly-regular, parallel phase lamellae with periodicities below 50 nm are easily obtained using 5W benchtop lasers. The eutectic films behave according to classic Jackson-Hunt theory, except with a Jackson-Hunt constant that differs from bulk. This is believed to arise from the inherently broader distribution of lamellar periodicities in 2D films vs. 3D bulk. When composition deviates from the eutectic by just a few atomic percent, chaotic structures featuring tortuous lamellae may occur. Solitary tilt waves, oscillatory instabilities, and extreme lamellar branching events arise due to inherent instabilities associated with the moving solid-liquid interface during hypoeutectic solidification. These instabilities are amplified as the solidification speed in reduced, seemingly at odds with traditional understanding of liquid/solid interfacial instability due to constitutional supercooling. This may be qualitatively understood with reference to the solidification microstructure map that is well-known for bulk Al-Cu alloys.
Support of the NSF under grant DMR-1663085 is gratefully acknowledged.