Control/Tracking Number: 1025-A-256-ICMAT
Activity: Abstract
Current Date/Time: 10/19/2024 9:20:01 PM

Melt-front model of inhomogeneous laser melting of gold thin films

References:
[1] Tadesse A. Assefa, Yue Cao, Soham Banerjee, Sungwon Kim, Dongjin Kim, Sunam Kim, Jae Hyuk Lee, Sang-Youn Park, Intae Eom, Jaeku Park, Daewoog Nam, Sangsoo Kim, Sae Hwan Chun, Hyojung Hyun, Kyung Sook Kim, Pavol Juhas, Emil S. Bozin, Ming Lu, Changyong Song, Hyunjung Kim, Simon J. L. Billinge and Ian K. Robinson, Science Advances 6 eaax2445 (2020)
[2] Ian K. Robinson, Jack P. Griffiths, Robert Koch, Tadesse A. Assefa, Ana F. Suzana, Yue Cao, Sungwon Kim, Dongjin Kim, Heemin Lee, Sunam Kim, Jae Hyuk Lee, Sang-Youn Park, Intae Eom, Jaeku Park, Daewoog Nam, Sangsoo Kim, Sae Hwan Chun, Hyojung Hyun, Kyung sook Kim, Ming Lu, Changyong Song, Hyunjung Kim, Simon J. L. Billinge and Emil S. Bozin, IUCrJ 10 656-661 (2023)
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Abstract:
Background and Objectives: The role of domain boundaries in the electrical and mechanical properties of crystals is known from electrical conductivity measurements and theoretical modelling. The models can be tested with ultrafast lasers at high power levels sufficient to melt a thin film in a single shot.
Methods: We performed ultrafast time-resolved diffraction experiments at the X-ray Free-electron Laser (XFEL) facility in Pohang, Korea [1]. We studied 300 nm polycrystalline thin films of gold evaporated onto silicon nitride windows, melted by a Ti-sapphire laser pulse.
Results: By analyzing the evolution of the X-ray diffraction lineshape, we established separate roles for the electron and phonon contributions in the melting dynamics. We deduced that the laser energy is primarily transmitted into the crystal at the grain boundaries, converting to heat which diffuses into the grains and melts them, as shown in Fig 1. The appearance of liquid was tracked by pair-distribution function analysis and found to have a slight time dependence following melting [2].
Discussion and Conclusion: We concluded that the melting process is highly heterogeneous, commencing at the domain boundaries [1], shown in Fig 1. The localized electrical and mechanical properties are intimately connected with the short time-scales accessible in XFEL-based diffraction experiments.

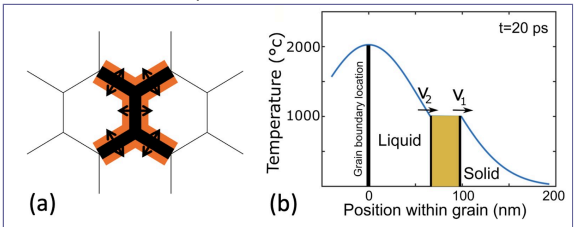

Figure 1. (a) Melt-front migration model of ultrafast melting initiated at grain boundaries or domain walls in a polycrystalline thin film. (b) Heat diffusion model of an impulse of heat applied to a grain boundary at position zero and time zero. The temperature profile is calculated after 20 ps of evolution, assuming the thermal parameters of gold. The colored block represents the delay due to latent heat of gold.

Author Disclosure Information:

I. Robinson: None.
Topics (Complete): Advanced Characterisation of Materials at Atomic Level using Electrons, X-rays and Neutrons
Presentation Preference (Complete): Oral Presentation
Status: Complete

Feedback