Ultrafast Laser-Induced Heating and Melting Dynamics of Aluminum Thin Films

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What is the outcome or accomplishment? (1-2 short sentences describing it and why it is transformative; 50-word maximum suggested)*

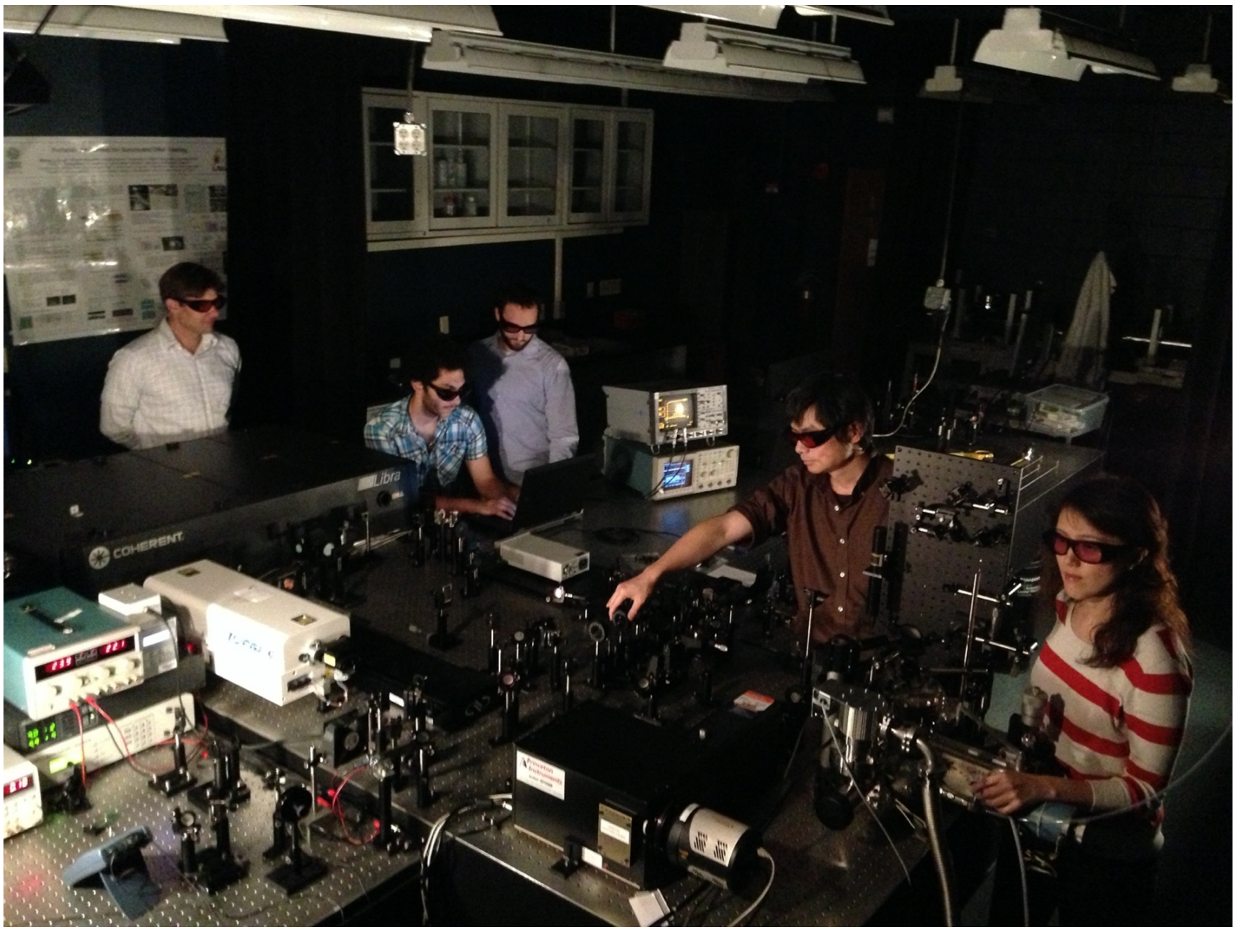
Laser-induced ultrafast heating and melting dynamics of aluminum thin films have been investigated under varying laser powers and metal thicknesses for improved modeling of selective laser melting for 3D printing and additive manufacturing applications. A characteristic length scale of the heat penetration depth (about 200 nm for aluminum) was experimentally determined.

What is the impact? (1-2 simple sentences describing the benefits for science, industry, society, the economy, national security, *etc.*; suggested 50-word maximum)

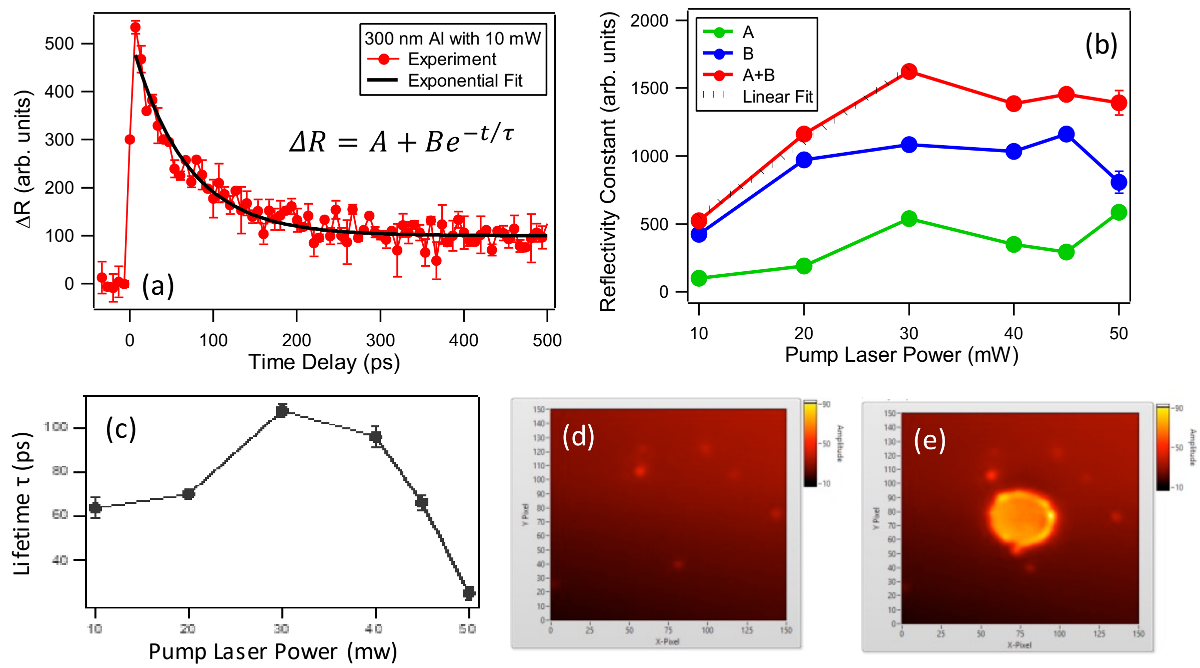
Using ultrafast pump-probe reflectivity measurements combined with optical microscopy, studies on fundamental laser-metal interactions are conducted which can be used for optimizing laser-based 3D printing of metal parts. The work is especially relevant for extending this field towards the nanometer and micrometer length scales of resolution.

What explanation/background does the lay reader need to understand the significance of this outcome? (1-2 paragraphs that might include, for example, more on who, when, where; NSF's role; support from multiple directorates/offices; what makes this accomplishment unique; additional intellectual merits; or broader impacts such as education, outreach, or infrastructure improvement that are integral to this outcome; suggested 150-word maximum)

Aluminum thin films of varying thickness ranging from 20 nm to 700 nm are deposited on a silica substrate and studied using ultrafast laser pump-probe reflectivity. For each sample, the power-dependent ultrafast reflectivity time traces are acquired in order to determine properties such as the electron-photon coupling lifetimes, melting thresholds, and changes in reflectivity. Additionally, the samples are imaged using optical microscopy both before and after the laser irradiations to confirm the laser power threshold for melting. The results indicate that the nanomaterial thin film becomes bulk-like as the thickness becomes larger than the characteristic heat penetration depth, which is approximately 170 nm for aluminum. At thicknesses below this length scale, the melting threshold is significantly lower in power and the electron-phonon coupling lifetimes are faster as compared to the thicker, more bulk-like thin film samples. This work was conducted by a team of Consortium for Innovation in Manufacturing and Materials (CIMM) scientists working in collaboration in the Departments of Chemistry, Physics, and Chemical Engineering at Louisiana State University.



Ultrafast laser laboratory for selective laser melting studies at Louisiana State University. (From left to right) Prof. Louis Haber, Dr. Rami Khoury, Dr. Joel Taylor, Dr. Zhenyu Zhang, and Dr. Jisun Kim.



(a) Ultrafast reflectivity time trace for 300 nm Al thin film with 800 nm pump laser at 10 mW. (b) Reflectivity constants and (c) electron-phonon lifetimes for 300 nm Al thin film as a function of pump laser power. Optical microscopy images of 300 nm Al thin film (d) before and (e) after laser-induced melting damage.