Collateral damage induced by femtosecond lasers

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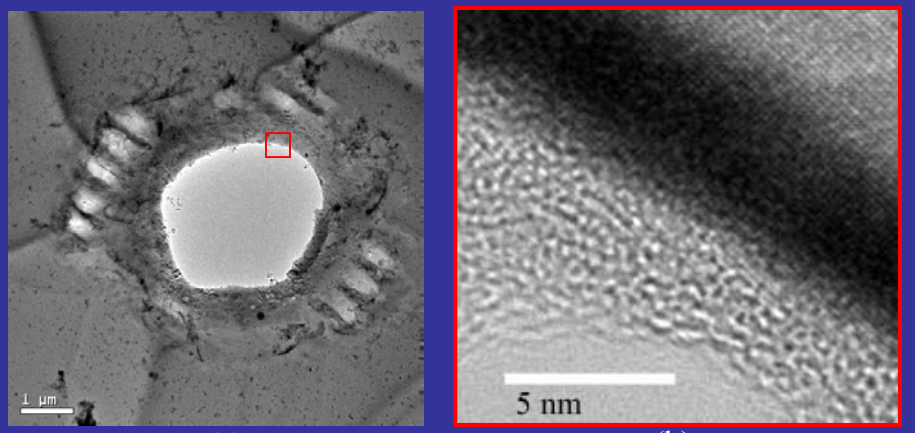
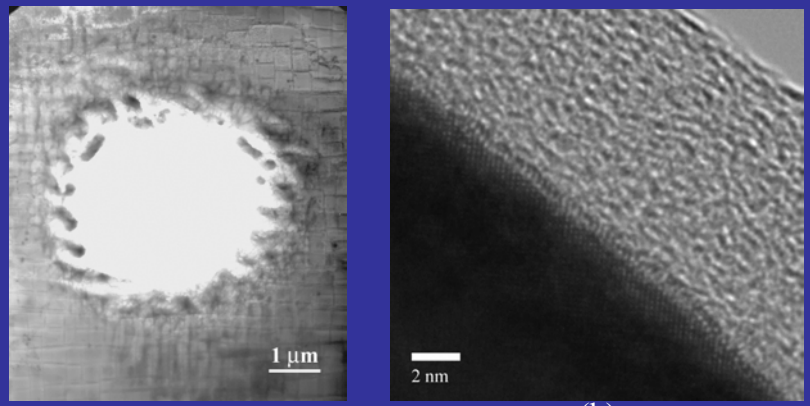
- The purpose of this study is to directly observe the extent of structural modifications to the adjacent area of a femtosecond laser ablated region.

- Pre-thinned foils of single-crystal silicon and a Ni-based superalloy were irradiated by single and multiple femtosecond laser pulses. Investigation of the edges of the resultant holes using transmission electron microscopy shows evidence of amorphized edges for both materials. However, the single-crystal material seems to be unmodified by observation of lattice fringes only 3-10 nm from the amorphous edge. This indicates that negligible heat was generated and subsequently dissipated into the immediate area surrounding the irradiated region.



(a) (b)

Fig. 1. TEM images of (a) a hole drilled in Si(100) using 200 pulses at 310 mJ/cm^2 and (b) the edge of the hole.



(a) (b)

Fig. 2. TEM images of (a) a hole drilled in a Ni-based super alloy using multiple pulses and (b) a high resolution image of an edge of a single pulse exposure.

Does a 15 Å native oxide alter the femtosecond laser ablation of Si (100) ? (Yes it does!)

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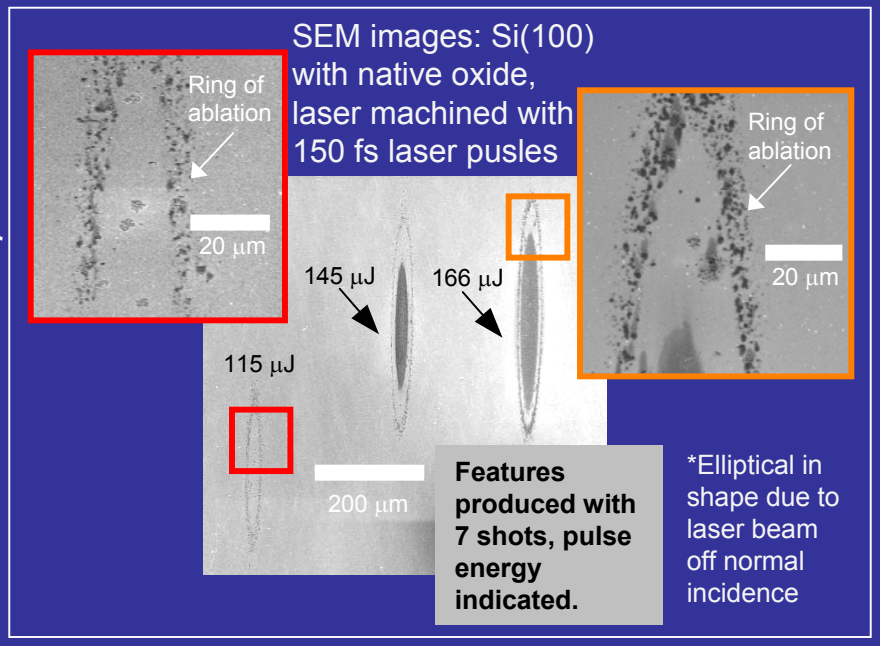
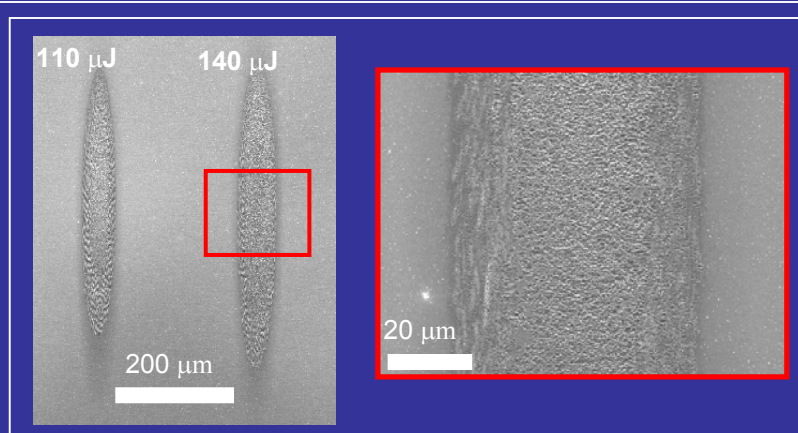
- Si is one of the most widely studied materials in history. Ultrafast laser/Si interaction is no exception. Yet, almost all of these studies ignore the native oxide. In order to gain a greater understanding of the interaction between ultrashort femtosecond (fs) lasers and materials, we studied the fs laser ablation crater morphology and fs laser ablation threshold Si(100) with and without a 14-25 Å native oxide layer.
- We have discovered interesting differences between the ablation characteristics of Si (100) with and without native oxide. Primarily, upon multiple shot laser ablation near the threshold for damage we observe an ablation ring on samples with native oxide, which is not present under the same ablation characteristics on atomically clean Si (100). The presence of the ring is proposed to result from a laser induced modification of the surface oxide which has the effect of limiting the ablation of the underlying bulk Si(100). Additionally, the ablation threshold (minimum energy required to ablate or remove material from the surface) for Si(100) was found to increase with the presence of the native oxide. This increase was found to correspond with what is expected from the Fresnel intensity transmission coefficient where the presence of thin oxide layer will limit the laser intensity transmitted into the underlying Si(100), which is largely responsible for the ablation.





Femtosecond laser machining Ni/Al reactive foils (without igniting them)

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- The purpose of this study is to demonstrate controlled micron-scaled cutting of explosive multilayer foils using femtosecond pulse length lasers.
- Particular systems of multiayer bimetallic nano-laminates can be ignited using an external thermal or electrical source. Initiated interdiffusion between metal layers causes an exothermic reaction that can self-propagate through the entire multilayer.
- By using multiple femtosecond laser pulses, we are able to remove material while also minimizing thermal energy dissipation into the foil. Thus, interlayer diffusion is prevented and no ignition of a self-propagating reaction occurs.
- Single pulse exposures (Fig. 3) demonstrate a digital, layer by layer, material removal process where depth penetration is energy dependent.

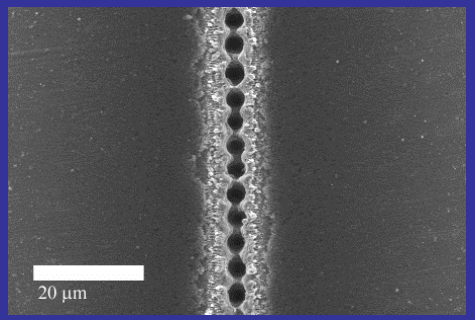


Fig. 1. SEM image of a line cut into a Ni/Al using 12.6 J/cm^2 pulses

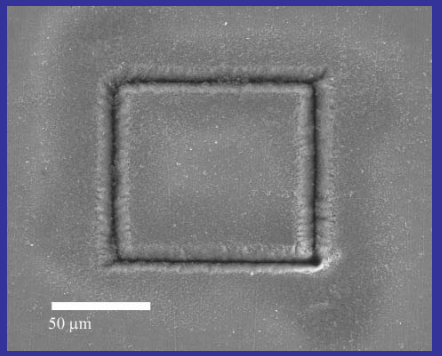
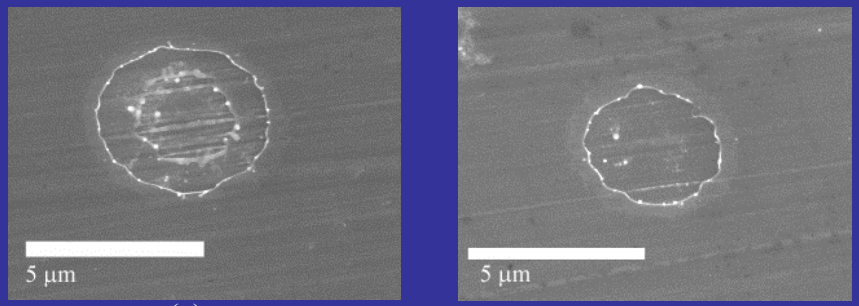


Fig. 2. SEM image of a square pattern cut into a Ni/Al using 12.6 J/cm^2 pulses



(a) (b)

Fig. 3. SEM micrographs of single pulse irradiation at fluences of (a) 0.81 J/cm^2 and (b) 1.62 J/cm^2 in a Ni/Al multilayer foil.

Femtosecond Laser Assisted MBE (FLAMBÉ)

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• Education

Post-Doc:

Paul VanRompay is a post doc supported by non-NSF funds but helps with the NSF related research

Grad Students (work highlighted on earlier slides):

Yoosuf Picard is a graduate student who is funded by this program and is also funded in part by Sandia National Laboratories. He is studying the extent of heat and collateral damage during ultrafast interaction. He will be the primary FLAMBÉ researcher this year.

Joel McDonald is also supported partially by this program and he receives additional support from the Applied Physics program at Michigan. He is studying the morphological evolution during ultrafast laser ablation.

Undergraduates:

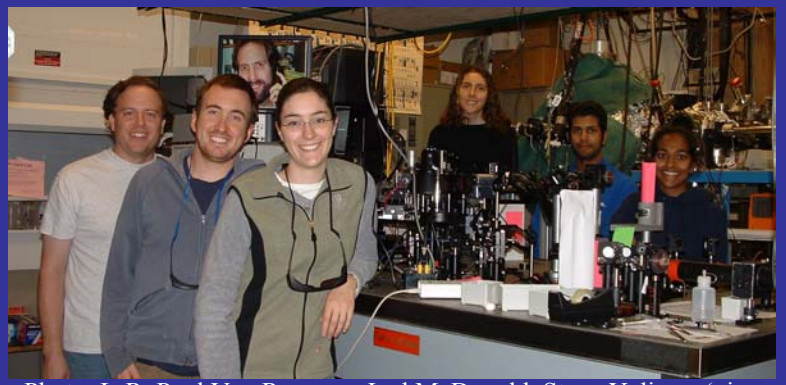
Kristen Tebo is a 4th year Electrical Engineering Student receiving REU funds with this program. She is working on Co deposition on Si in UHV to use silicide phase transformations away from laser damaged regions as nano-thermometers.

Brad Thomas is a 3rd year MS&E student working on the role of grain boundaries on damage thresholds in Cu.

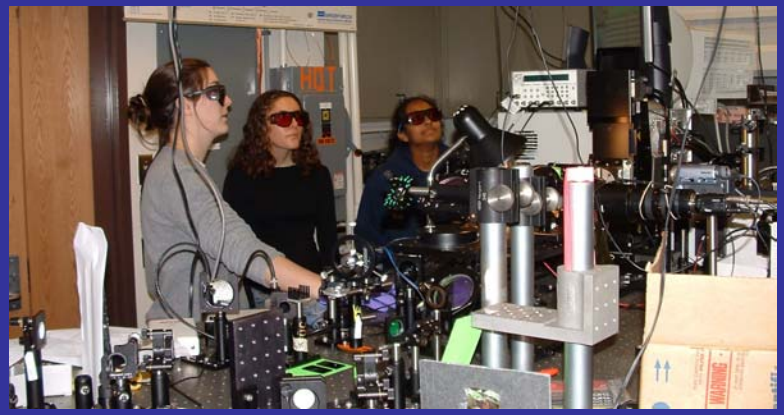
Kathy Ray and Vanita Mistry started working with us as Freshmen last year and are continuing to work with us this year. They assisted Joel and Yoosuf last year and this year are helping Joel extend his work to thicker thermally grown films.

•Outreach

We actively participate in our Undergraduate Research Opportunities Program at the University of Michigan. This program gets Freshmen into the research environment in the first few months of their college careers.



Group Photo: L-R, Paul Van Rompay, Joel McDonald, Steve Yalisove(via computer link),Kristen Tebo, Kathy Ray, Yoosuf Picard, Vanita Mistry.



Kristen is showing Kathy and Vanita how to use the 4-axis manipulation stage to perform an experiment.