Pushing the Limits in Opacity Target Fabrication and Metrology*

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Precision targets are central to all HEDLA programs. Areal density knowledge with an accuracy of 2% to 3% on the actual samples being shot is of utmost importance to the Solar Opacity (and other) experiments. These experiments compare the increased x-ray opacity of metals at higher temperatures and densities against that at room temperature and density.

In order to improve the areal density accuracy over that of previously available targets, we decided to take a highly unconventional approach and reverse engineer target fabrication from a metrology perspective: (1) The most relevant measurement should be x-ray absorption as the principle property being investigated is x-ray opacity. (2) The characterization has to be done nondestructively on the actual sample because the sample-to-sample variation of the substrate wafer is already larger than the desired error budget. (3) It is preferable for the sample to remain on the wafer as the previous method of gluing to a support washer negatively impacts foil flatness, complicating radiation coupling during the shot. (4) The metal pattern definition should be achieved through lithography since future inter-diffusion studies could mandate more complex structures not achievable with contact masking.

With this in mind, we developed a unique photolithography-based approach to produce opacity targets integrated onto silicon rings designed for ease of measurement and fielding. Such samples have been shot on Sandia’s Z machine and have produced very clean spectra for solar opacity studies. More complex samples with line patterns have been produced for inter-diffusion studies of metallic species under warm dense plasma conditions. We have also constructed an automated “AutoEdge” system in-house to push the limits of x-ray absorption measurements: (1) We have compiled five x-ray databases, namely X-COM, XFFAST, LBNL, LLNL, and SNL, into a single program for direct comparison and sample data analysis on the fly. (2) We have benchmarked gravimetric areal density on single-element foils to validate and differentiate x-ray databases at the 1% level, which calibrates measurement accuracy. (3) We have verified and improved measurement precision via empirical photon-counting statistics studies.

With such efforts, the areal densities of our currently produced samples are known with an unprecedented precision and accuracy. These targets are currently being shot in support of HEDLA and other experimental campaigns. The improved knowledge of the x-ray databases is also broadly applicable to other programs.

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