Determination of the Graphite Incubation Parameter in the Ultrafast Regime using the D-Scan Technique

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Abstract: Graphite ablation threshold for ultrashort pulses was measured for pulses superpositions spanning 4 orders of magnitude using the D-Scan technique. Three ablation regimes were identified, and for incubation effects, graphite accumulates defects as a metal.

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1. Introduction

A commercial graphite sample (Alfa Aesar, 99% purity) was used to study the ultrashort ablation threshold and its dependence on the pulses superposition in this material using the Diagonal-Scan (D-Scan) method [1]. In this fast and simple technique, the sample is moved diagonally across the waist of a focused laser beam, and a profile with two lobes is etched on its surface. Measuring the lobes width immediately provides the ablation threshold (F_{th}), and its value along with the sample transversal speed and pulses repetition rate gives the pulses superposition (N) [1].

A Ti:Sapphire CPA system (Femtopower Compact PRO HR/HP) generated 800 nm pulses, which were focused by a 75 mm focal length doublet. The beam was attenuated and dispersion compensated to provide ~70μJ, 25 fs pulses at the focus. A 3-axes computer controlled translation stage moved the sample across the beamwaist, under atmosphere. Translation speeds from 0.05 to 20 mm/s were used together with 20, 100, 500 and 4000 Hz repetition rates to cover 4 orders of magnitude of pulses superpositions, and 30 traces were etched in less than an hour.

The irradiated samples were imaged by optical and scanning electron microscopes, and the lobes were measured in the micrographies, allowing the calculation of F_{th} and N.

2. Results

The etched traces showed 3 distinct morphologies, each one limited by a D-Scan profile shown in Fig. 1a. These morphologies correspond to the high (blue in Fig. 1) and low (red) fluence ablation regimes, and a third regime in which the ablation occurs in the edge of polishing grooves on the sample surface and does not propagate to smooth regions (green). Fig. 1b shows, for each regime, the experimental F_{th} dependence on the pulses superposition and the function $F_{th}(N)=F_{th,1}\ N^{S-1}$, commonly used to describe incubation effects in metals, fitted to the data. Single pulse ablation thresholds ($F_{th,1}$) obtained from the fits for are 1.3(5), 0.122(3) and 0.052(2) J/cm^2, and 0.91(5), 0.909(4) and 0.94(1) for the incubation parameter (S) for the high, low and "grooves" regime, respectively.

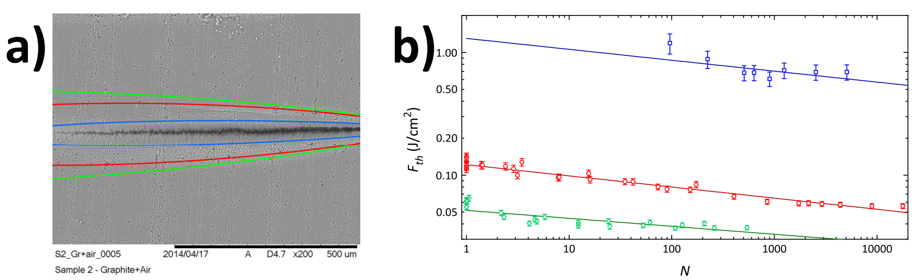

Fig. 1. a) D-Scan profiles over a TEM micrography showing 3 distinct ablation morphologies; b) graphite ablation threshold dependence on the pulses superposition for the three morphologies.

3. Conclusions

Using the D-Scan we identified three ablation regimes in graphite and determined, for each regime, the single shot ablation threshold and incubation parameter. The lowest threshold regime can possibly be lowered by a better surface polishing. Additionally, graphite behaves as a metal regarding defects accumulation for incubation effects.

4. References

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