Controlling the damage threshold of Si with SiO_2 coatings upon irradiation with Mid-IR femtosecond laser pulses

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A key issue in the use of high-power mid-infrared (Mid-IR) laser sources for a plethora of applications is the investigation of the exciting laser driven physical phenomena taking place in materials coated with dielectric films. Here, we present a theoretical investigation of the ultrafast processes and thermal response upon excitation of two-layered complexes consisting of fused silica thin films placed on silicon substrates with ultrashort pulsed lasers in the Mid-IR spectral regime. We demonstrate that the control of the underlying ultrafast phenomena and the damage threshold (DT) of the substrate are achieved via an appropriate modulation of the thickness of the SiO_2 film. It is shown that a decrease of DT by up to ~30% (depending on the pulse width) compared to the absence of coating is feasible emphasising the impact of coatings of a lower refractive index than the substrate. The conditions for patterning the Si substrate due to the excitation of interfacial electromagnetic modes are also discussed. The remarkable predictions can be employed for the development of new optical coatings and components for nonlinear optics and photonics for a large range of Mid-IR laser-based applications.

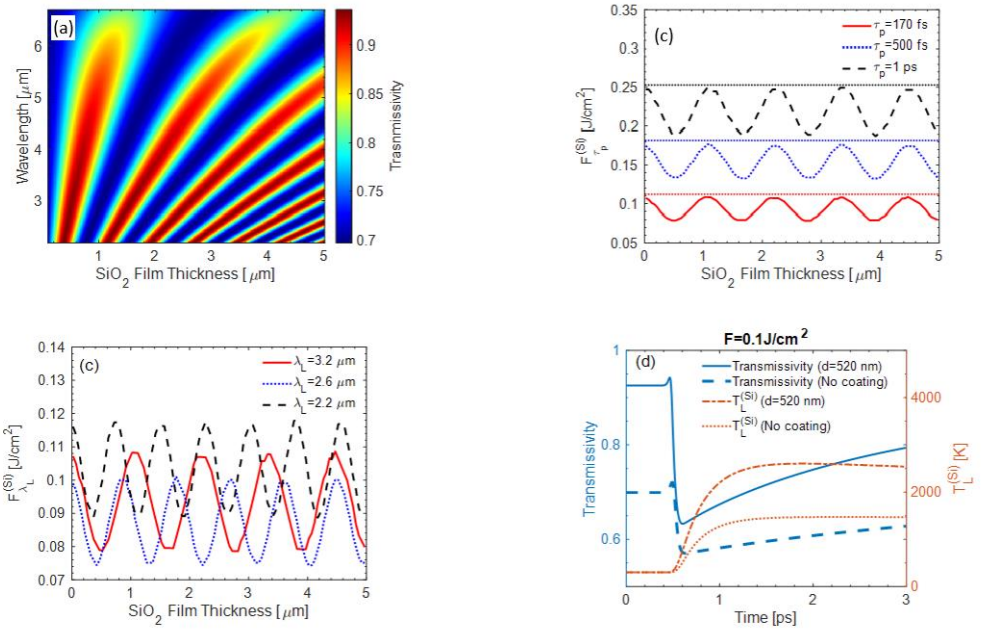

Figure 1: (a) Transmissivity of SiO_2/Si as a function of d and the laser wavelength, (b) damage threshold (DT) calculation as a function of the SiO_2 thickness at various pulse durations (τ_p=170 fs, 500 fs, 1 ps). Horizontal *dotted* lines above the curves in (b) correspond to DT of Si in absence of the coating for corresponding τ_p. Simulations are illustrated at λ_L=3.2 μm, (c) damage threshold as a function of the SiO_2 thickness at various laser wavelength (λ_L=2.2 μm, 2.6 μm, 3.2 μm). Simulations are illustrated at τ_p=170 fs, (d) Transmissivity in Si for d=520 nm and in absence of SiO_2 (F=0.1 J/cm^2). Simulations are illustrated at λ_L=3.2 μm.

References:

[1] Tsibidis G.D., Stratakis E., 'Ionization dynamics and damage conditions in fused silica irradiated with Mid-Infrared femtosecond pulses',

[2] Tsibidis GD., Stratakis E., 'Influence of Antireflection Si coatings on the Damage Threshold of fused silica upon irradiation with Mid-IR femtosecond laser pulses', Optics Letters 48 (18), 4841 (2023).

[3] Tsibidis G.D., Stratakis E., 'Controlling the damage threshold of Si with SiO2 coatings upon irradiation with Mid-IR femtosecond laser pulses' (submitted).