Interaction of pulse laser radiation of 532 nm with model coloration layers for medieval stone artefacts

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Introduction

Since about four decades, laser cleaning has been established as a practicable method in conservation science of stone artefacts [1,2]. Many ancient objects such as epitaphs (Fig. 1) exhibit multilayer polychrome coatings. Conservation interventions require systematic diagnostics of the stability towards laser irradiation and in respect to a multilayer analysis [3]. In this study, polychromic models, classical pigments – minium, lead white and zinc white – in an acrylic binder, were produced and investigated [4]. The aim was to identify their threshold fluences as well as their incubation factor at a laser wavelength of 532nm.

Experimental

A frequency-doubled Nd:YAG laser, (10ns, 20 Hz, 532nm; SpectraPhysics) was used. Samples were positioned on a computerized x-y-stage in order to generate arrays with varying fluence (F) and number of pulses (N) (Fig. 2). Evaluations were performed microscopically.

Results

The evaluation of the squared diameter \( D^2 \) (squared diameter) of the modified region vs. the log of the fluence \( F \) allows to determine the Gaussian beam radius \( \omega_0 \) and the threshold fluences at respective \( N \).

\[
D^2 = 2 \omega_0^2 \ln \frac{F}{F_{th}}
\]

Incubation (variation of threshold fluences with \( N \)) can be quantified by the evaluation of the incubation factor \( \xi \) [1,3]. The closer \( \xi \) is to 1, the weaker is the incubation.

\[
F_{th}(N) = N^{\xi-1} F_{th}(1)
\]

Conclusion

Threshold fluences can be calculated from the \( D^2\text{-ln}F \) plot.

• Incubation is much weaker in the case of minium than for lead white and zinc white.
• This is related to the dielectric properties of these materials.
• Minium exhibits a band gap of 2.14eV. Therefore, radiation at a photon energy of 2.3eV (532nm) leads to a strong resonant absorption. Incubation can be almost neglected.
• Due to the high absorbivity of minium the threshold fluence is low.
• Incubation by laser-induced defects and band gaps.

Flash energy (2J) can be calculated from the incubation factor, the threshold fluence is low.

References