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Study on coating exfoliation damage of KDP component under laser irradiation by surface analysis

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Abstract

Potassium dihydrogen phosphate (KDP) is a key component for laser frequency conversion. Here, we study the damage of KDP coating caused by multiple laser irradiation under low flux in vacuum. Time-of-flight secondary ion mass spectrometry (ToF-SIMS) with $C60^{n+}$ cluster sputtering in combination with scanning electron microscopy (SEM) and atomic force microscopy (AFM) were employed to provide detailed information on the three dimensional chemical composition and the deterioration process of this kind of coating. The detailed chemical changes in the process of coating densification caused by UV laser irradiation were explained by analyzing the coating thinning after irradiation. The conversion from Si–O–Si bond to Si–O–K bond supported coating hardening after damage. Furthermore, a dynamic evolution law of coating deformation after laser irradiation was obtained by comparing it with non-irradiated coating. Interface bonding between KDP and coating, stratified chemical information across the coating thickness direction, and relationship between damage and environ mental condition were investigated. A possible mechanism of coating exfoliation after laser irradiation was proposed based on the above analysis. This work can be used as reference to optimize the laser coating over KDP substrate in laser facilities.

Experiment

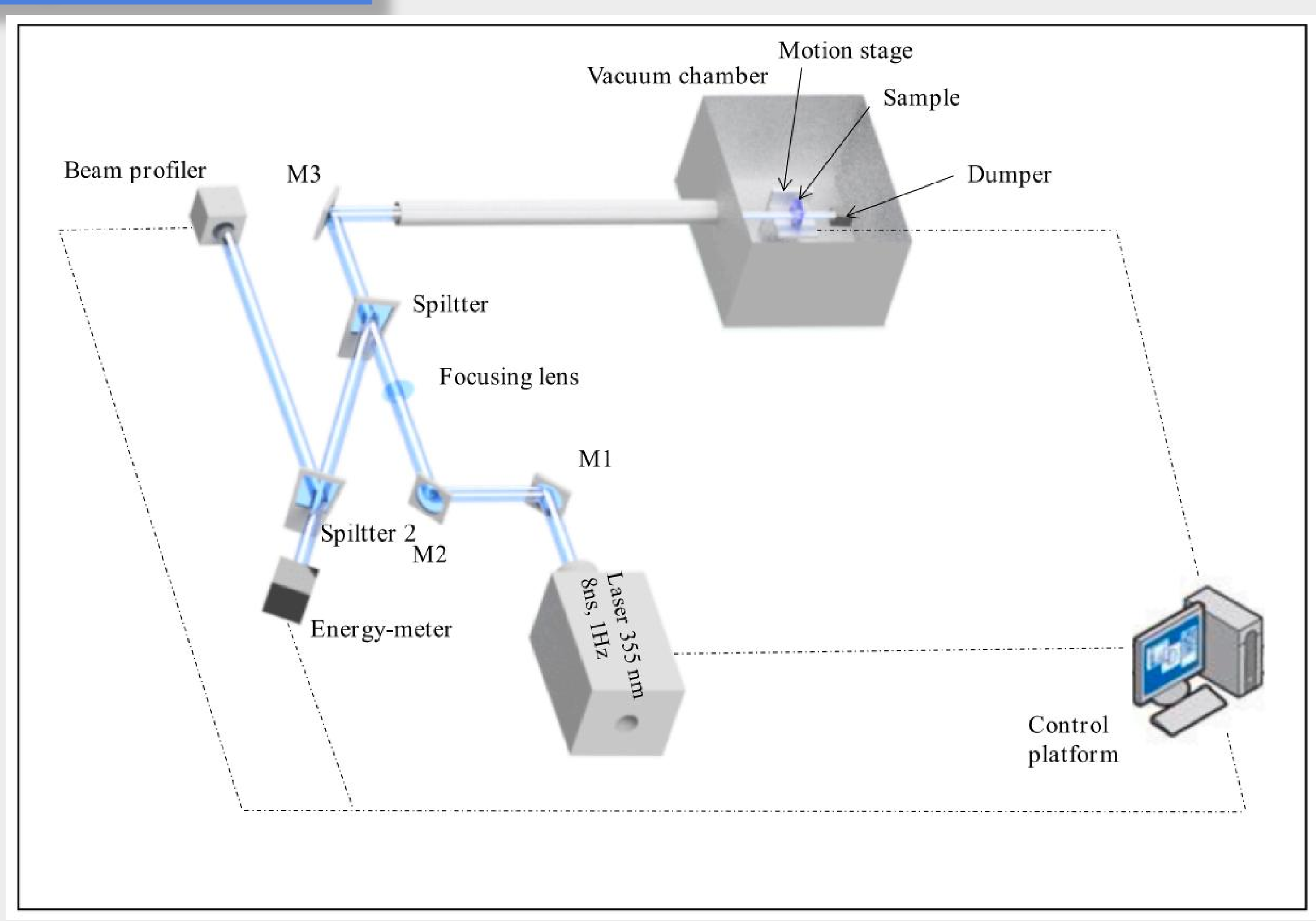

Fig. 1. Optical path diagram of simulated experimental device.

In this experiment, KDP AR coating sample was irradiated by **1500,2000 and 2500 laser pulses** individually, and the laser pulse width valued **8ns**, the pulse energy density is **$4J/cm^2$**.

Results & Discussion

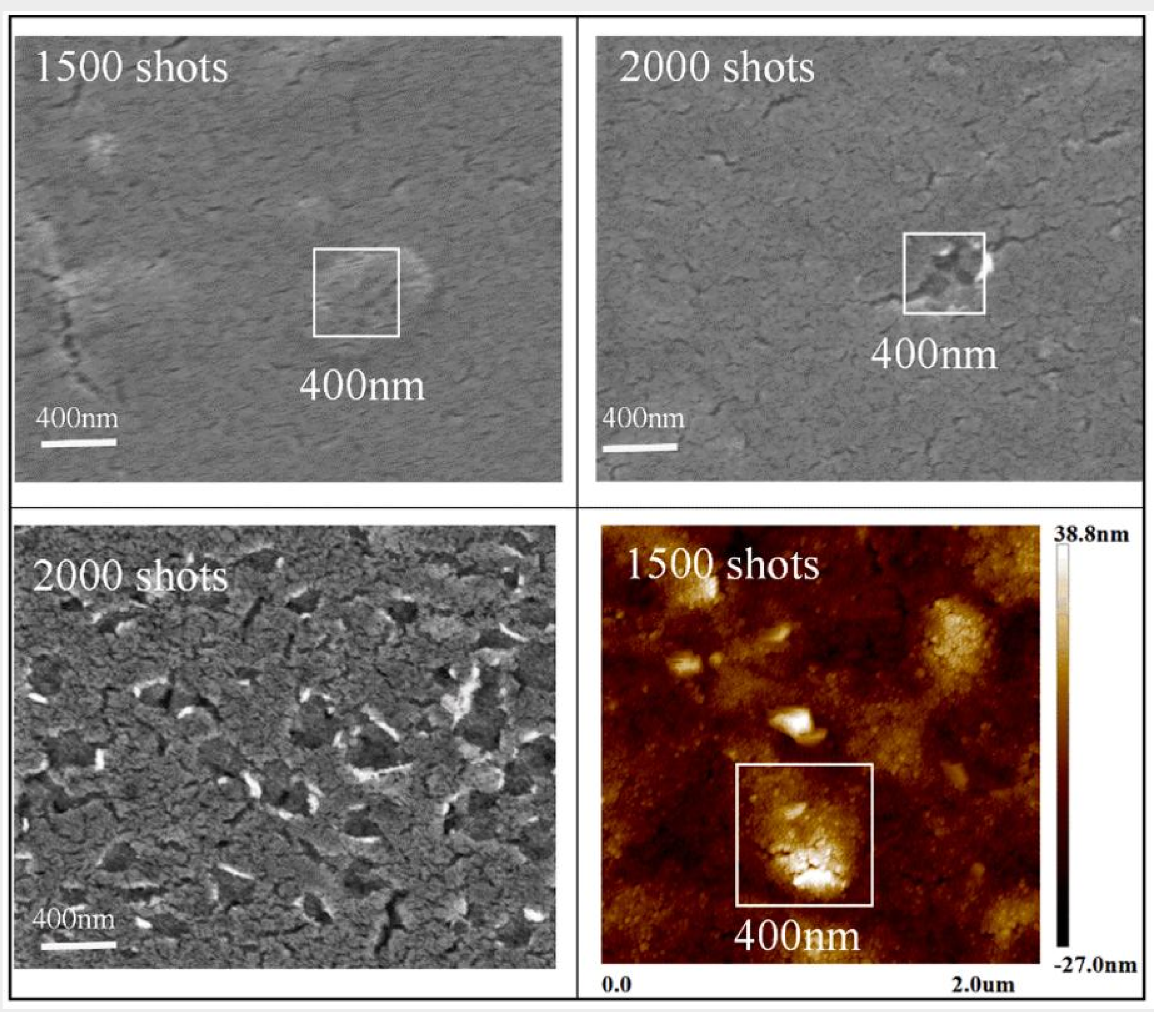

Fig 2: Results of experiment irradiated by laser pulses

Results & Discussion

Table 1
Type and counts of ion products of the coating in three states.

Relative atomic mass(m/z)	Product	As-Prepared coating	Undamaged part	Damaged part
73	Si—$(CH_3)_3$	7495	3996	8291
43	Si—CH_3	9788	6125	14,632
45	Si—OH	90,177	43,014	40,834
72	Si—O—Si	34,956	13,207	6959
83	Si—O—K	39,625	10,403	17,791
95	P—O_4	182,717	144,624	192,074

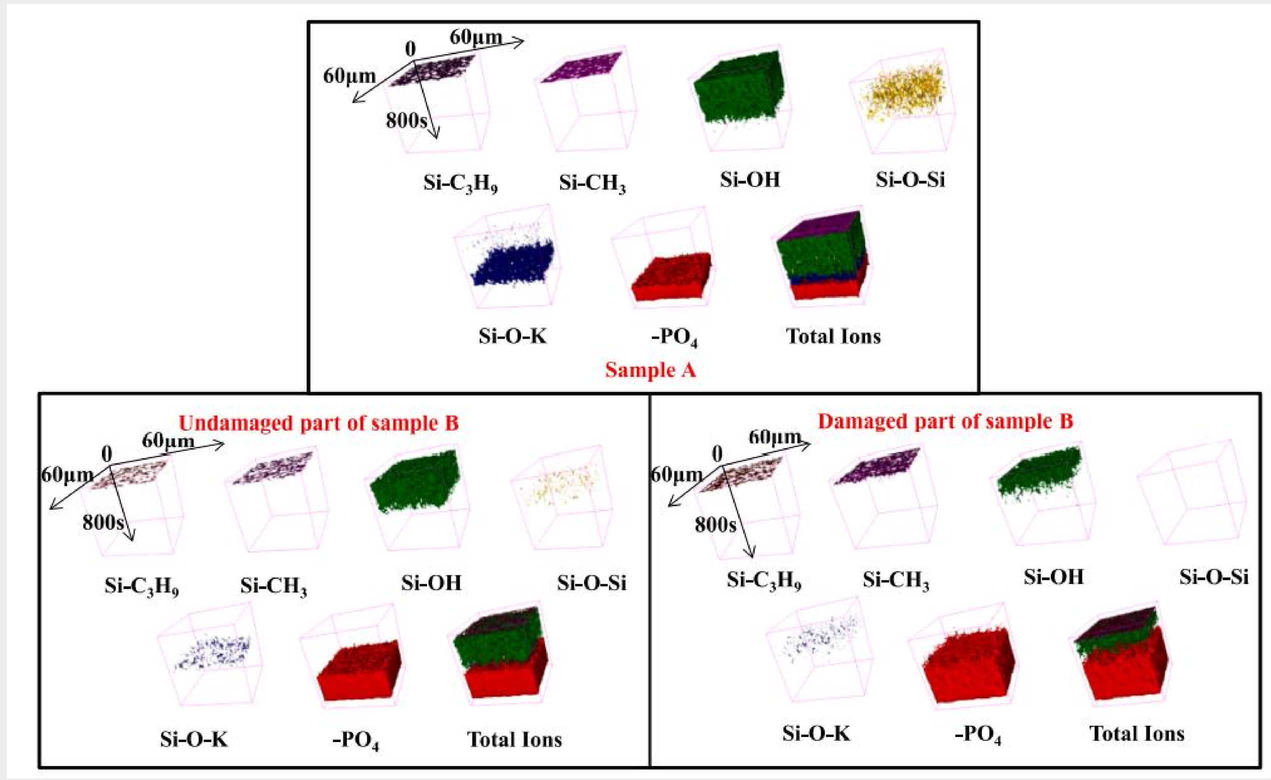

Fig 3: Results of coating chemical structure by ToF-SIMS

Variation of interface layer

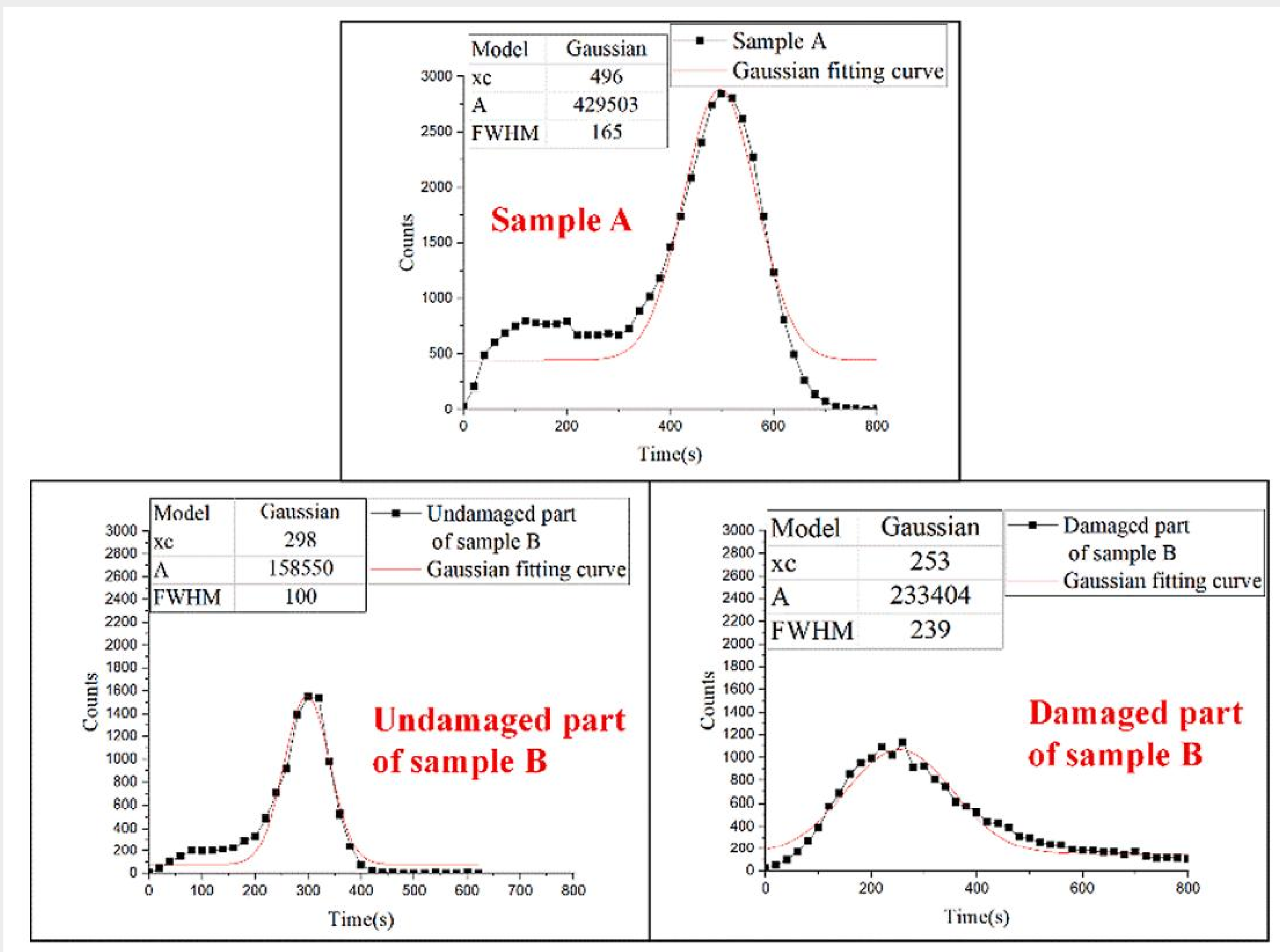

Fig. 4: Gaussian fitting curves of Si–O–K bond content in three coating states.

Conclusion

Clear exfoliation damage was confirmed over the antireflective laser coating applied for KDP component which exhibited whitish damage visually. The chemical information of this coating was reconstructed via ToF-SIMS analysis, in which Si–O–K was verified to be the connection structure at the coating/substrate interface as well. The loss of porosity upon porous laser coating was found the most crucial reason to cause damage under low-flux laser irradiation, and the coating densification and organic pollution was proved to be responsible for the porosity loss through experiments. Initial humping deformation over this coating was identified at the beginning of laser interaction, and further burst and connection of this deformation would finally result in the large-area whitish macroscopic damage.