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STUDIES OF SAPPHIRE PHOTOABLATION BY LASER-INDUCED FLUORESCENCE AND PHOTOTHERMAL DEFORMATION MEASUREMENTS

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Crystalline sapphire displays a low, 0.6 J/cm^2 , threshold for etching with 193 nm excimer pulses. Understanding this low-threshold etching involves knowledge of the pathways by which laser energy gives rise to material removal. An accurate knowledge of surface temperature during irradiation appears sufficient to differentiate between classical thermal vaporization and electronic, I.E. photochemical mechanisms for etching.

To distinguish between these two mechanisms, we initially utilized laser-induced fluorescence (LIF) measurements¹. This technique deduces surface temperature from the energies of AlO radicals in the etch plume as it expands rapidly away from the surface.

The data indicates that the rotational/vibrational energy distribution of AlO is equivalent to a surface temperature of $\approx 500\text{K}$. On the other hand, translational energy distributions have much higher energies which partly originate in plasma effects above the surface. Both the above results imply a photochemical, I.E. direct electronic etching mechanism. Pulsed photothermal deformation (PPTD) results² complete the picture in two important ways. First, the results indicate that the surface temperature approaches $\approx 430\text{K}$ in the region just below threshold. This confirms that plasma and gas kinetic (collisional) effects do not noticeably alter the observed AlO rotational/vibrational results $\approx 500\text{K}$ for the region above threshold. Second, the PPTD results indicate that the surface energy absorption leading to ablation is a large one photon absorption at 193 nm. This surface absorption is notably reduced by annealing and chemical etching.

Finally, this absorption implies the order of 1 electron-hole pair/oxygen atom on the surface. Such a density of electron-hole pairs is of the magnitude anticipated to produce etching since the surface chemical bonding is significantly altered.

Third, LIF measurements (using the Mulliken bands near 230 nm) on diatomic carbon radicals provide several interesting contrasts to the sapphire work. Laser etching of carbon takes place by a thermal vaporization process. The LIF results correctly reflect the anticipated thermal equilibria, with the kinetic energy being somewhat modified by gas-phase collisions. Overall, one thus has increased insight into and confirmation of the facts that the etching pathway for sapphire which is accessed by high energy (6 eV) UV photons involves a photochemical reaction and LIF correctly measures the surface temperature.

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2 - R.J. VON GUTFELD, F.A. MCDONALD and R.W. DREYFUS, Appl. Phys. Lett. V. 49, 1059 (1986) and V. 50, 1491 (1987) and F.A. MCDONALD, R.J. VON GUTFELD and R.W. DREYFUS, Proc. IEEE Ultrasonics sym. (1986) P. 403.