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## 2.D Automated Control and Monitoring of Ablation-Layer Coating

The ablation layer of a laser-fusion target is the outer coating, typically composed of a low-Z material where the laser energy is absorbed. Heat from the absorbed laser energy causes the material in the absorption region to expand radially outward; this results, by conservation of momentum, in the implosion of the inner layers of the target. At LLE, ablation layers composed of a hydrocarbon polymer, parylene (poly-para-xylylene),[1] have been deposited on microballoon targets[2] of high degrees of smoothness and uniformity.[3]

The necessity of developing the automated ablation-layer deposition system now in use resulted primarily from the fact that the manual process was excessively time-consuming. The manual process required the continuous attention of an operator, usually for several hours per target. In addition, the coating thickness of any given target could not be controlled to within the precision required for certain experiments. An operator, with skill and practice, could obtain the desired coating thickness to within an accuracy of only 10 to 15%. The automated system operates virtually unattended, and with the new thickness monitoring system in place, the deposition process can be stopped precisely enough to control final thicknesses to within 10 nm. This tolerance is typical of those required for thermal transport experiments on the OMEGA system, where thermal electron conduction through precisely known thicknesses of ablation-layer material was measured.[4]

The parylene deposition process consists of the three steps illustrated in Fig. 25: (1) vacuum sublimation at elevated temperature of a stable crystalline dimer, 2,2-paracyclophane; (2) the pyrolysis at high temperature of the dimer to form p-quinodimethane; and (3) simultaneous deposition and polymerization of the p-quinodimethane to form parylene. Sublimation usually occurs at 100-200°C, pyrolysis at 650°C, and deposition at room temperature. By carefully controlling the deposition process, very smooth and uniform conformal coatings can be deposited on microballoon laser-fusion targets. Additional technical details for this process were reported in LLE Review, Volume 9.[3]

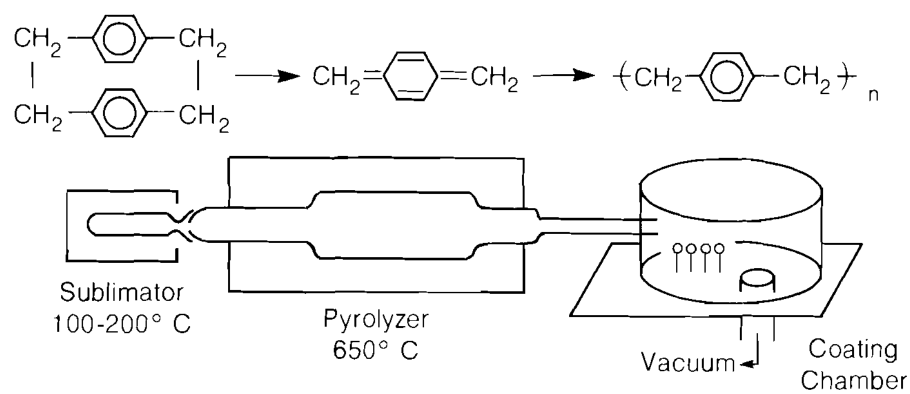


*Fig. 25*
*The parylene process is used to coat laser-fusion targets with ablator layers. This system has been completely automated.*

In the manual operation of the parylene coating system, the final coating thickness could be controlled only by maintaining a known deposition rate for a specified length of time. The deposition of a 10-$\mu$m coating, for example, required up to eight hours of careful work. This deposition rate was known only as an empirically derived function of the sublimation temperature and system pressure. Since these factors were both measured and controlled by an operator, the process was intrinsically time-consuming and approximate.

In the automated mode of operation, the parylene coater, by means of optical reflectometry, continuously monitors the thickness of the growing film on a glass "witness" slide placed in the coating chamber near the targets being coated. Extensive studies at LLE have verified that the coating thicknesses on the slide and on the targets are virtually identical. The parylene coating on the witness slide forms a multiply reflecting surface whose reflectivity to monochromatic He-Ne laser light ( $\lambda$ = 632.8 nm) varies sinusoidally with the increasing thickness of the coating. The modulation is caused by the interference between the reflections from the parylene/vacuum interface and the parylene/glass interface. This sinusoidal modulation advances one cycle for each thickness increment, $\Delta t$, equivalent to a half-wavelength in optical thickness, or $\Delta t = \lambda/(2n)$, where n is the index of refraction of parylene (see Fig. 26). In the automated system, a microcomputer fits the reflectometer data to a $\cos^2(\pi t/\Delta t)$ function of the total thickness t, and thus continuously and accurately monitors the layer thickness. In contrast, an operator, by reading a strip-chart record of the reflectivity, can monitor the coating thickness only to within 1/8 of a cycle, or 25 nm of parylene. Although this accuracy is adequate for ablation-layer fabrication, a skilled operator is still needed to monitor the process parameters, do thickness calculations, and terminate the coating process when the appropriate thickness is reached.

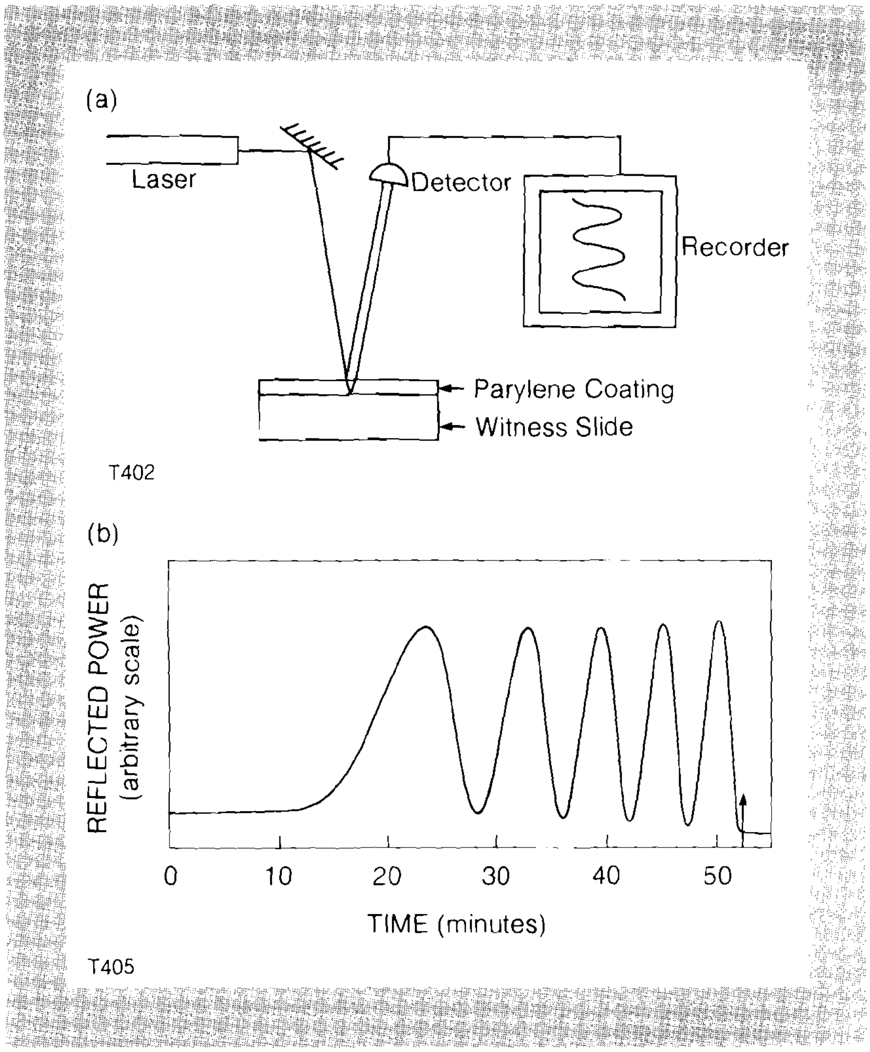


*Fig. 26.*
*a) Optical reflectometry has provided a cost-effective method of real-time monitoring of parylene coating thickness.*
*b) Actual reflectometer output for a 1-μm film. The arrow on the reflectivity scan shows the time at which the sublimator was cooled. The fixing of the reflectivity value at this time indicates the rapid termination of the coating process.*

The new, fully automated system performs all monitoring and safety functions. In addition to processing the reflectometer data, the microcomputer controls the sublimator heater, the sublimator cooling fan, and the sublimator and vacuum gauge heaters according to input from the reflectometer, the vacuum gauge, and the sublimator temperature sensor. Upon deposition of the desired thickness of parylene, the microcomputer activates mechanisms which remove the heater from the sublimator and turn on the sublimator cooling fan. This immediately terminates the coating growth and an alarm is sounded to notify the operator.