THE DEVELOPMENT OF ULTRATHIN POLYIMIDE FOR LASER TARGET AND OTHER APPLICATIONS

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ABSTRACT

This paper presents summary results of a development project to optimize submicron polyimide films for applications such as gas-filled laser targets and filters for x-ray astronomy. Data on deflection and burst pressure is presented along with deflection vs. pressure for aluminized films. It is shown that submicron thick polyimide is significantly stronger than Lexan of the same thickness. Also included is data on transmission as a function of photon energy and wavelength.

I. INTRODUCTION

Luxel Corporation has developed techniques for fabricating submicron thick polyimide films over the last five years. A principal application is for use as windows on gas-filled laser targets such as hohlraums and the "gasbag" targets that the Lawrence Liver-more National Laboratory (LLNL) has used to simulate large National Ignition Facility (NIF) scale plasmas. The other principal use is as optical blocking filters for x-ray astronomy missions such as the Advanced X-ray Astrophysics Facility (AXAF).

Luxel began experimenting with ultrathin polyimide films in 199 1. The company was awarded a Phase I SBIR contract from NASA Goddard Space Flight Center in 1992 and successfully demonstrated feasibility of making polyimide filters for x-ray astronomy. Based on this, an SBIR Phase II two year development contract was awarded by NASA Goddard in 1993. This opportunity allowed Luxel to devote a major effort toward developing and refining the processes for fabricating ultrathin polyimide films optimized for application to laser targets and x-ray astronomy.

Lexan (polycarbonate) has been the principal support film for exploding foil laser targets and x-ray astronomy for many years, but polyimide is becoming the material of choice because of its superior strength as shown in Table 1. Also, there is some indirect evidence from vibration and acoustic testing in spacecraft applications (not yet verified analytically) that sub-micron films are actually stronger than what might be anticipated based on bulk material properties.

	Tensile Strength (kg/cm^2)	Flexural Strength (kg/cm^2)
polypropylene	343	490
polycarbonate	630	945
polyimide	1190	1100

Table 1. Bulk Strength Properties of Polypropylene, Polycarbonate, and Polyimide[1]

Polyimide can also withstand much higher temperatures (greater than 300°C) than most polymers. This property allows polyimide to accept vacuum depositions of metals better than Lexan.

II. POLYIMIDE DEVELOPMENT TEST RESULTS

Luxel Corporation has developed techniques for fabricating free standing polyimide films ranging in thickness from 300Å to 40,000Å. Procedures for curing polyimide have been optimized for thin film applications where both strength and ductility are important. Also, improved methods for aluminizing the polyimide films by vacuum deposition were developed. In the course of this effort, a number of test programs were conducted, and the following paragraphs summarize some of the more significant results of these efforts.

Figure 1. shows the test results of testing four different polymers as free standing films for which the deflection in the center of a 5mm aperture was measured as a function of pressure applied behind the aperture. Measurements were made by viewing the sample through a stage mounted microscope with a micrometer for measuring position, i.e. deflection normal to the film. Since the pressure puts the film under tension as it deflects, the test is a measure of tensile strength. Material stiffness would enter in if the films had significant thickness, but since they are of submicron thicknesses, film stiffness is an insignificant factor. The slope of the curves is an indication of the ductility or initial resistance to stretching.

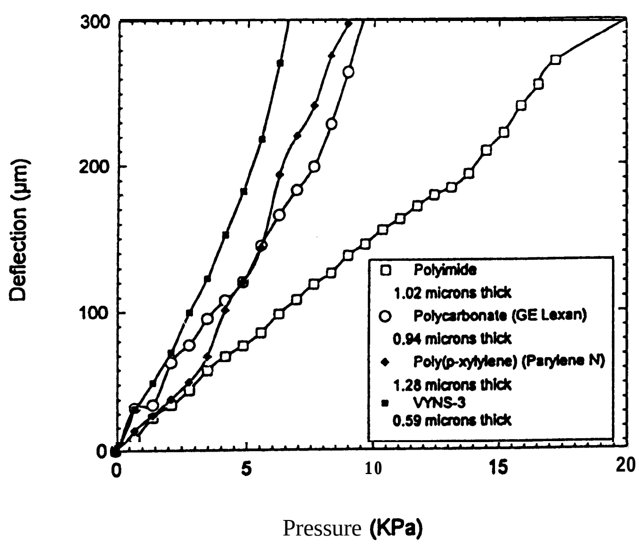

Figure 1. Deflection vs. Pressure for various polymers

The materials tested were not all the same thickness, but the data suggests that polyimide is the strongest material. The data in Figure 1 was taken over a small range of pressures. Figure 2 shows a direct comparison between Lexan and polyimide over a much larger range of pressures where deflection is plotted as a function of pressure for three different samples which have been averaged. This data suggests that 1 µm polyimide is much more resistant to stretching than Lexan. Figure 3 shows burst pressure as a function of film thickness for both Lexan and polyimide. The data show that over the range of submicron thicknesses, polyimide is 2 to 3 times stronger than Lexan. Clearly, polyimide not only resists stretching under pressure, it is ultimately stronger than Lexan when tested to failure.

In order to design filters and windows that must withstand some pressure, it is necessary to be able to predict what thickness of material is required for a certain pressure differential and aperture size. To this end, a large number of windows were built and tested to determine burst pressure as a function of aperture size. The resulting data is shown on Figure 4. As can be seen, on a log log plot, straight lines can be drawn to accurately predict burst pressure. An exponential equation can be used as a design tool for predicting window performance.

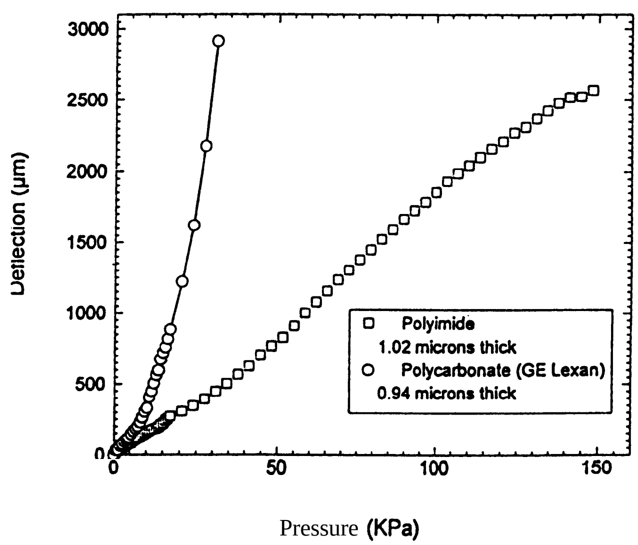

Figure 2. Deflection vs. Pressure for Lexan and polyimide

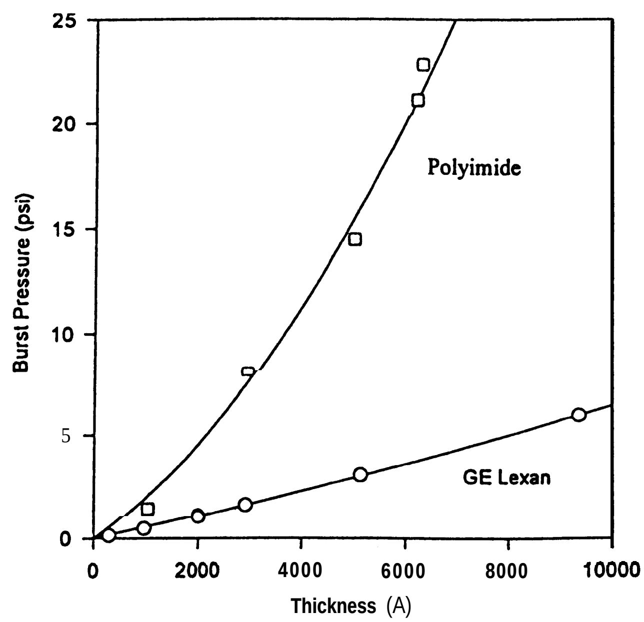

Figure 3. Burst pressure vs. Thickness for Lexan and polyimide

Figures 5 and 6 address the effect of aluminization on polyimide. Figure 5 shows deflection vs. pressure for various thicknesses of aluminum on about 2 100Å of polyimide, and Figure 6 shows the same data for various thicknesses of aluminum on about 6400Å of polyimide. Figure 6 in particular shows that the aluminum seems to add to the stiffness of the combined foil. The aluminum is vacuum deposited onto free standing polyimide film.

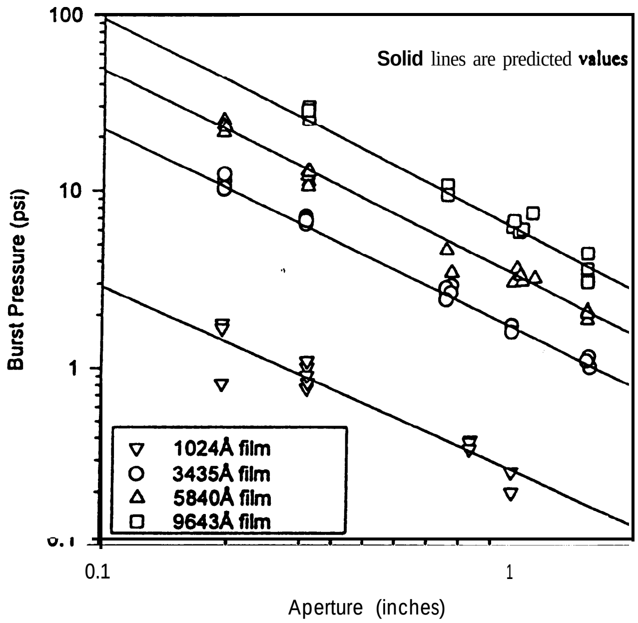

Figure 4. Burst pressure vs. Aperture size for various thicknesses of polyimide

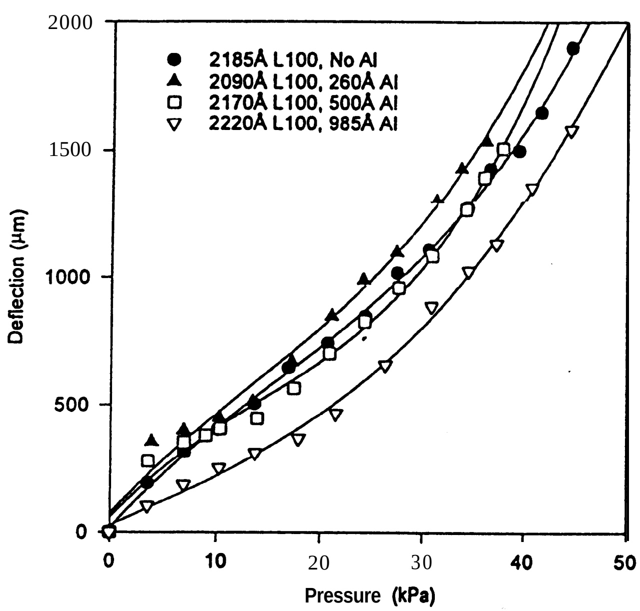

Figure 5. Deflection vs. Pressure for polyimide near 2 1 00Å thick with various thicknesses of Aluminum

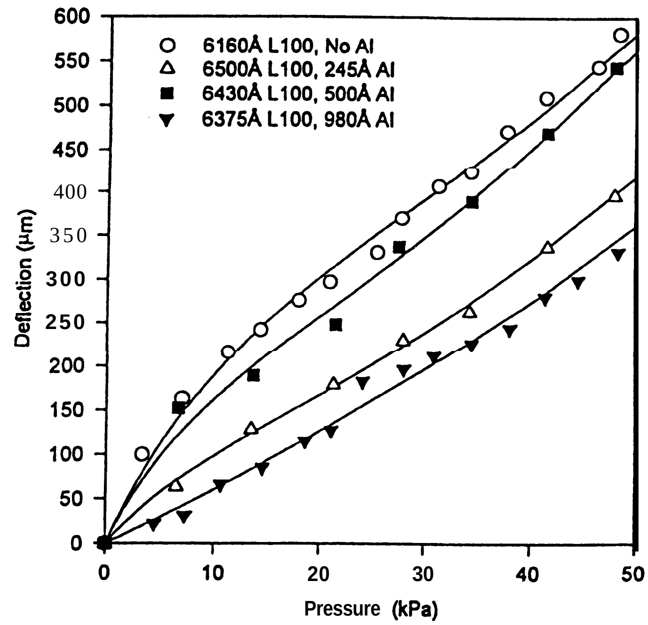

Figure 6. Deflection vs. pressure for polyimide near 6400Å thick with various thicknesses of Aluminum

III. OPTICAL PROPERTIES

Optical properties of polyimide are of interest, particularly in the soft x-ray portion of the electromagnetic spectrum where the transmission is substantially reduced. Transmission of polyimide 1000Å thick as a function of wavelength is shown on Figure 7, and transmission as a function of photon energy is give in Figure 8. Henke constants[2] have been used to model transmission, and as can be seen, the agreement between the measured data and the model is very good in the EUV and soft x-ray portion of the spectrum. The transmission through polyimide remains low in the ultraviolet region and the material becomes essentially fully transmitting between 3000 and 4000Å in the visible region of the spectrum.

IV. APPLICATIONS

Polyimide is becoming widely used for many ultrathin film applications because of its superior strength. Luxel Corporation provides polyimide windows assembled and pressure tested on customer supplied hohlraum bodies for Lawrence Liver-more National Laboratory (LLNL), Sandia National Laboratory (SNL) and the Atomic Weapons Establishment (AWE) in the United Kingdom. Luxel also fabricates gasbag laser targets for LLNL. These targets are unique in that polyimide windows are applied to both sides of an aluminum washer and then expanded under pressure until the assembly is almost spherical in shape.

This application requires that the polyimide cure cycles be optimized to balance strength and ductility such that the material can expand under load without bursting. After expanding, the gasbag targets are pressure tested to insure that they will withstand one atmosphere or more in use. They have been utilized at LLNL to produce ignition-scale plasma conditions with Nova[3]. Polyimide is also used extensively for filters for x-ray astronomy and for x-ray research on synchrotron beamlines. Polyimide's ability to withstand high temperatures is an especially useful property for solar astronomy since filters on telescopes pointing at the sun must withstand a very high heat load. In many applications, the polyimide is metalized. A large number of different metals are used, but aluminum is utilized most often because it provides excellent blocking of visible light while transmitting broadly in the x-ray region.

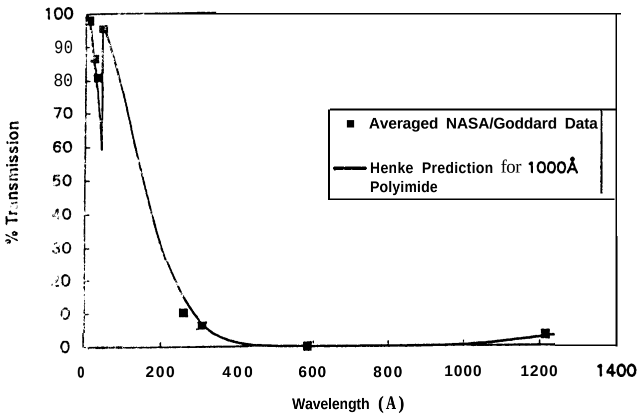

Figure 7. Percent transmission vs. wavelength for 1000Å polyimide

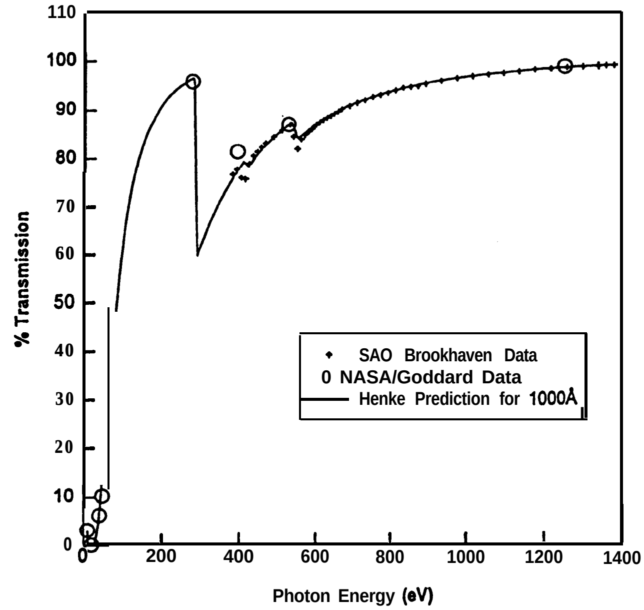

Figure 8. Percent transmission vs. photon energy for 1 000Å polyimide

V. REFERENCES

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2. B.L. Henke, E.M. Gullikson, and J.C. Davis, "X-ray interactions: photoabsorption, scattering, transmission, and reflection, E=50-30,000 eV, Z=1-92," *Atomic Data and Nuclear Data Tables,* 54(2), p. *18* 1 (1993)
3. Lawrence Livermore National Laboratory, *Internal Confinement Fusion Quarterly Report,* Vol. 6-1 (October-December 1995)