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Laser Damage Threshold studies on Ion Plated Perylene Thin Films

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Abstract

Perylene thin films were deposited on cleaned glass substrates by ion plating technique in r.f.glow (10 MHz) sustained by argon gas of pressure 0.399 Pa. Laser-induced damage threshold of these thin films has been studied employing dye Q-switched Nd: glass laser emitting 25 ns pulses at 1062 nm. It is observed that the threshold increases with the decrease in thickness of the film. Typical damaged sites caused by the irradiation of the laser pulses have been depicted. The threshold energy densities of the ion plated films for the thicknesses 150,201 and 295 nm have been found to be 25.420,10.030 and 6.398 J/cm^2 respectively. These results have been also compared with those of vacuum evaporated films. The possible damage mechanism followed in these films has been identified as impurity dominated one.

Key words: lasers, thin films

Introduction

One of the burning problems encountered with high energy laser systems is the occurrence of irreversible, destruction change in the optical components caused by the irradiation with a high power laser pulse (Radhakrishnan et al. 1985). Recently a number of laser dyes have been described with the generation of stimulated radiation due to relatively novel photochemical mechanism (Chou et al. 1984; Acuna et al. 1986a, Acuna et al. 1986b). Perylene, a laser dye, is a promising active laser material due to the four level flourescing system of that molecule (Boguslavskil & Vannikov 1970). As it has exhibited lasing action (Berlman, Rohni & Goldschmidt 1973; Sakurai 1976), it may be employed in the design of thin film dye lasers. Now-a-days laser induced damage studies in thin films have received much attention (Dyumaev et al. 1983; Radhakrishnan & Sathianandan 1986; Sajimol et al. 1988). This paper deals with the laser-damage threshold studies on ion plated perylene films. The results of the present investigation have been compared with those of vacuum deposited films (Subbarayan et al. 1988), which we reported earlier.

Experiment

In ion plating technique (Murayama & Takao 1977), pure perylene (99 + %, Aldrich chemicals company, USA) was evaporated from a molybdenum boat in the presence of r.f.(10 MHz) glow in argon (IOLAR-2) and deposited on to a well cleaned glass substrates. At the time of evaporation, the r.f. power was kept at 125 watts and the substrate holder was negatively biased to about 150 volts. The pressure of argon gas inside the vacuum chamber was maintained at about 0.399 Pa to sustain the glow discharge. The film thickness was determined using a multiple beam interferometer (Fizeau fringes) (Tolansky 1948). The structure of the film was identified as amorphous by x-ray diffraction and the non-decomposition nature of the film was established by IR spectroscopy and thin layer chromatography in the way described elsewhere (Subbarayan et al. 1987).

Three stages are involved in the measurement of the laser damage threshold. The first stage is to irradiate the sample at several flux levels, some of which induce damage; the second is to measure the absolute characteristics of the pulse, and the third is to determine which shot in the sequence caused damage. It is essential that the spatial and temporal profile of the laser remains a constant during the entire operations since there is no way to determine whether an unexpected result obtained, was due to the fluctuation in the laser or an exceptional property of the damage sample.

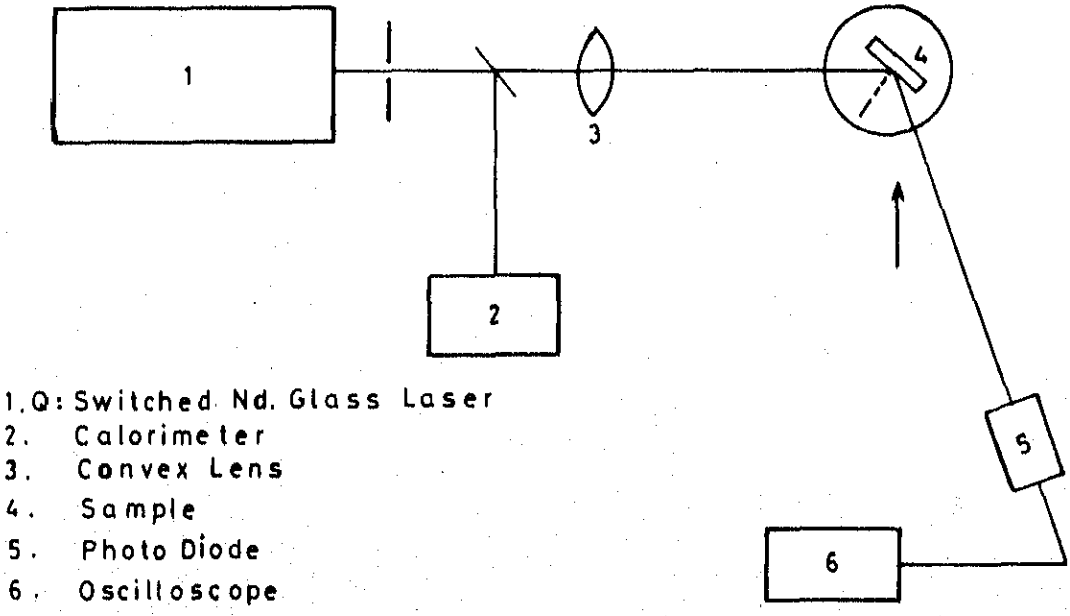

Figure 1. Schematic representation of laser-induced damage threshold measurement.

Fig. 1 depicts a schematic diagram of the experimental set up to measure the damage threshold (Subhash & Sathianandan 1983). The laser used in this study was a Nd: glass laser Q-switched by Kodak 14015 dye in 1,2 dichloroethane with a pulse width of about 25 ns (FWHM). The beam structure was multimode and was approximately Gaussian in profile with a diameter of about 4mm. The laser output was passed through a biconvex lens of 17 cm focal length, onto the film sample. The sample mounted on a rotating platform was oriented so that the angle of incidence of the laser beam was 56^0 thereby avoiding the multiple beam interference in the glass substrate. The pulse width of laser was monitored on a Tektronix Model 466 DM storage oscilloscope with a Hewlett Packard HP_2 4207 Photodiode. The energy incident on the thin film sample was monitored by a 1 inch Scientech disc calorimeter (Model 38-0101).

Throughout a particular set of experimental study, the laser output energy was kept constant by maintaining a constant voltage on the capacitor bank of the flash lamp discharge circuit. With the present set up absolute energy measurement was not possible for every damage attempt. However, an energy calibration was made before and after each set of damage tests. To begin with, the distance of the sample from the lens was adjusted such that the shot impinging on the film damages it. After the film sample was pushed in the direction indicated by the arrow mark (Fig. 1) to enable the next shot to impinge on a site adjacent to the previous one. The film position is thus shifted, as it moves away from the focus of the lens the power density incident on the sample is decreased. Once the damage threshold is attained, with the subsequent shots there will be no damage at all. On completion of the test run, the damaged sites examined with a metallurgical microscope (Carl Zeiss Jena EPY-TYPE:2) and the threshold damage location was identified. Once the shot which caused the threshold damage is identified, one can calculate the threshold energy density for the film material by knowing the area of the site upon which the laser beam incident from the geometrical considerations. By measuring the pulse width using CRO, the power density of the incident laser beam can be estimated.

Table 1. Comparison of Threshold energy densities for ion plated films and vacuum deposited films for various thicknesses

Deposition Technique	Thickness of the film nm	Threshold energy density J/cm^2
Ion plating	150	25.420
	201	10.030
	295	6.398
Vacuum deposition	147	19.880
	204	7.170
	295	4.971

The threshold energy densities computed for different thicknesses of the ion plated films are presented and compared with those of vacuum deposited films (Subbarayan et al. 1983) in Table 1. It is evident from the table that the threshold energy density increases in thickness for the film prepared by both techniques and also ion plated films are found to be with higher damage thresholds than the vacuum deposited ones.

For dielectric films (Lowdermulk et al. 1980; Walker et al. 1979), it has been reported that the threshold increases with absorptance and decreases with increase in film thickness (Walker, 1979). As the most noticeable feature, unique to the impurity model is the prediction of an increase in damage threshold with a decrease in film thickness, the mechanism followed in this film material may be an impurity dominated one. In this model a spherical absorbing particle embedded in a host material is considered. This impurity absorbs the incident radiation and its temperature rises, which ultimately results in melting, vapourization or stress fracture of the film material around the impurity. Hence it is quite reasonable that the maximum size of an impurity is limited by the film thickness, i.e. as the film thickness increases as does the impurity size. Hence the threshold energy density increases with decrease in film thickness.

The higher damage thresholds of ion plated films than those of vacuum deposited films may be attributed to the improved adhesion of films during ion plating process. Similar trends of damage threshold dependence on adhesence of the films has been observed earlier (Radhakrishnan & Sathianandan, 1986; Radhakrishnan, 1986).

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References

Acuna, A.U., Costela, A. and Munoz, J.M. 1986a,J.Phys.Chem.,**90**,2807.

Acuna, A.U., Amat, F., Catalan, J., Costela, A. Figuera, J.M. and Munoz, J.M. 1986b, Chem. Phys. Lett., **132**,567.

Berlman, I., Rohni, R. and Goldschmidt, C.R. 1973, Chem.Phys.Lett.,**22**, 458.

Boguslavskil, L.I. and Vannikov, A.V. 1970, Organic semiconductors and Biopolymers, Plenum Press, New York, 207.

Chou, P., McMarrow, D., Aartsma, T.J. and Kasha, M. 1984 J.Phys.Chem., **88**, 4596.

Dyumaev, K.M.,et.al. 1983, Sov.J.Quantum Electron., **13**, 503.

Lowdermilk, W.H., Milam, D. and Rainer, F. 1980, Proc.Symp.Laser Induced Damage in Optical Materials, NBS Special Publ.No. **568**, 391.

Murayama, Y. and Takao, T. 1977, Thin solid films, **40**, 309.

Radhakrishnan, P., 1986, Ph.D.Thesis, Cochin University of Science and Technology, Cochin.

Radhakrishnan,.P.and Sathianandan, K., 1986, Appl.Opt., **25** 1027.

Radhakrishnan, P., Sathianandan, K. and Vallabhan, C.P.G. 1985, Bull. Electro Chem., 1, 319.

Sajimol Augustine, M., Radhakrishnan, P., Jayalakshmi S. and Krishnapillai, M.G. 1988, Bull. Electro Chem., 4, 177.

Subbarayan, A., Balasubramanian, C. and Narayanadass, Sa.K. 1988, Phys. Stat. Sol(a), **108**,K31.

Subbarayan, A., Balasubramanian, C and Narayandass, Sa. K. 1987, Proc. 75th Indian Sci. Cong. Part III,20.

Subhash N. and Sathianandan, K. 1983, J.Appl.Phys., **54**, 423.

Tolansky, S. 1948, "Multiple Beam Interferrometry of surfaces and films" Oxford University Press, New Jersey.

Walker, T.W. 1979, Ph.D.Thesis, Part II, Air Force Int.Technol.,Ohio, 21.

Walker, T.W., Guenther, A.H., Fry, C.G. and Nielson, P. 1980, Proc.Symp.Laser Induced Damage in Optical Materials NBS Special Publ.No.568,405.