[AMN06] Determination of argon fluoride (ArF) excimer laser system and materials diagnosis

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Introduction

The growing interest in precise fabrication of micro and nano-structures such as optical component, lenses, sensor and devices makes the conventional approach no longer satisfactory for micro scale structure. Now, nano-technology has a big potential to revolutionize everything from medicine, industrial manufacturing and to computer within a few decades. Recently laser ablation of optical material have been carried out by a few group of researches including Srinivasan *et al.* (1982), Wee and Pak (2001), Pissadakis *et al.* (1999), Jitsuno *et al*. (1995), Dyer *et al.* (1996) and Naessens *et al.* (2003).

Polymer-based materials are becoming ubiquitous in a variety of high-tech application, e.g. specialty coating, automotive, aerospace, semiconductors and optical components. A constantly increasing use of polymer-based material has highlighted the need for better understanding of their physical, chemical and mechanical properties (Diakoumakos and Raptis, 2003). The polymer exhibits a variety of ablation characteristics depending on the irradiance parameters applied as described by Dyer *et al.* (1996).

As summarization, from all the papers and articles reviewed of laser ablation application in interdisciplinary field, it driven us an interest to study, diagnose and characterize the fundamental of laser ablation. Although the application is wide, our interest study is lay on interaction to the polymer material and have to focus our research in this field towards the optical fabrication and in order to find new applications.

Materials and methods

Basically, four types of sample which have different optical characteristic were employed as ablation materials. First sample was thermal paper, with an opaque characteristic purposely used for the calibration and comparison. Another three samples were comprised of different types of polymer material, which including high-density polyethylene (HDPE) plastic represented for translucent material characteristic, plasticised polyvinyl chloride (PPVC) and polymethyl methacrylate (PMMA) for transparent material. The materials were chosen because of their increasing used in a variety of high-technology application such as special coating, automotive, optical fabrication, semiconductor and others. Argon Fluoride (ArF) excimer laser model EX5-200/100 manufactured by GAMlaser was employed as the source of energy for the ablation works. The laser possesses a fundamental wavelength of 193 nm which produce ultraviolet laser radiation.

EXLASER laser control software is a 32 bit Windows based software application which controls all laser operation from a personal computer screen. There are 5 basic software screen that is laser control, refill, calibration, advance and setup screen (EX5 Manual, 2003). The setup screen is used to set the laser model and the excimer gas is being used. Laser control screen is the main screen to control the laser operation. There are a number of controls available on the screen shown such as thyratron warm up timer, power supply status, interlock, high voltage slider, repetition rate button, number of pulses button and start button.

The calibration was performed to diagnose and verify the performance of the laser beam. Prior to the ablation process, it is worth to calibrate the optimum performance of the excimer laser. In this case, several parameters was measured including power of the laser beam, repetition rate, number of pulses, high voltage and working distance. The optimum value out of these tests will be selected and utilised for the ablation process. Parameter such as high voltage, repetition rate and number of pulses were altered according to ablation experiment. When we increased high voltage, means high voltage input at the electrodes in cavity also increased, more photon will produced. Repetition rate

represent the frequency of trigger signal to the thyratron in laser chamber, higher repetition rate mean more pulses will be produced in one second. Number of pulses can be defined as duration of exposure. The exposed sample was visualised and recorded by using digital camera. The images then were transferred into personal computer and image processing software was used to analyse the data.

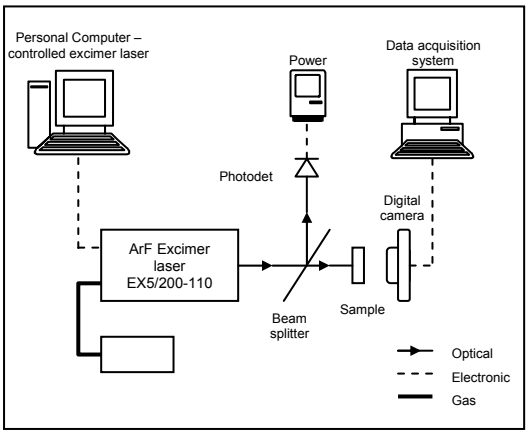

FIGURE 1 Schematic diagram of experimental set up for ablation process

Results and Discussion

a) Ablation by absorption mechanism

When a laser beam strikes onto a sample, a photoluminescence violet colour is existed in spot size. A visible white plume appeared during ablation works. When such photoluminescence induced on material, this will lead to physical and chemical alteration of surface properties (Kogelschatz *et al*., 2000). As heat is transferred to the surrounding material, the ablation will occur. The exposed area on the sample became carbonised.

The carbonised effect was studied in order to determine an absorption mechanism. The carbonised effect was recorded and analysed by using *x-profile* option in Matrox Inspector 2.1 software. The darkness of the carbonised spot image was represented a degree of an absorption mechanism. The darker the image, the greater the absorption occurs on the surface.

The PPVC sample which is transparent material transmitted other wavelength in the electromagnet spectrum. But with UV excimer laser is still capable to absorb the beam. This is a good indicator that, in future the PPVC material can be used to test the ablation effect.

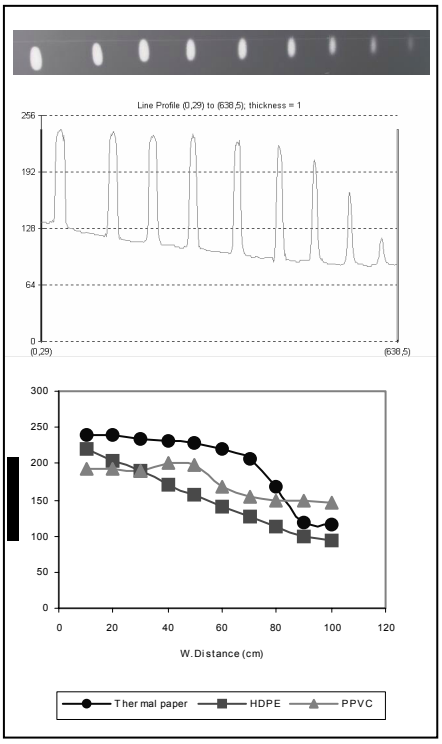

FIGURE 2 Determination of absorption using Matrox 2.1 software.

b) Refractive index changes

PMMA (Polymethyl methacrylate) is a versatile polymeric material that is well suited for many optical applications. Commonly used as a high resolution positive resist for direct write electron beam as well as ablation, microlithographic process and optical fabrication.

There was no carbonised effect when UV light was irradiated onto PMMA. So the changes of refractive index on the exposed area due to number of pulses were measured by using Brewster angle method.

The ablation effect does not clear in the early stage of exposure, however as the duration of exposure is increased, the bright spot become obvious

In this studied, the reflected beam was measured by using power meter, whereby He-Ne laser was used as an illumination source. The beam was polarized and directly focused onto the centre of the ablation spot. The PMMA was mounted on the rotating table. An incident angle of the beam was adjusted by rotating the table. The Brewster angle experiment was done in the region of 10 to 70

degree for PMMA sample, but more measurements were concentrated within the range of 50 until 70 degree because the refractive index for PMMA was around 1.4. The power of reflected beam was recorded against the incident angle and the minimum power determined.

The important part is the minimum power of reflected beam that indicates the Brewster angle. By obtaining the Brewster angle then the refractive index of the exposed area can be calculated.

TABLE 1 Refractive index value correspond to number of pulses

Number of Pulses	Brewster angle (θ^0_B)	Refractive index (n_2)
200	55.5	1.46
300	56.0	1.48
400	53.0	1.33
500	51.0	1.23
600	54.5	1.40
700	55.5	1.46
800	52.0	1.28
900	51.0	1.23

The average of two refractive index of Table 1 was used to plot a graph of refractive index against the duration of exposure

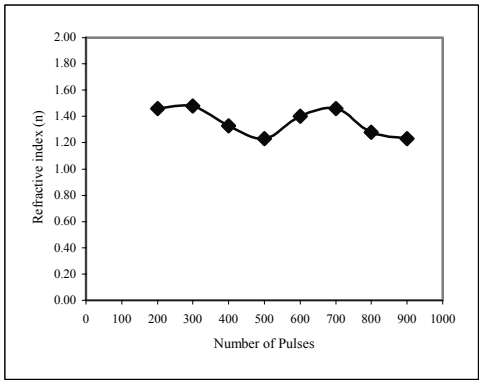

FIGURE 3 Refractive index of exposed area due to number of pulses

Under UV irradiation, although there was no carbonised effect on PMMA sample but the photodimerization still occurs. As a result, the refractive index was changed according to the alteration of chemical structure into another type of polymer and physically its allow the drawing of an optical pattern on the surface of polymer material. According to Pireaux *et al.* (1995), the UV exposed area not only due to the chemical modification but also to the structural changes.

The refractive index of PMMA before the ablation is 1.46, and that after the ablation works is 1.23 in the range of 200 to 500 pulses. Due to the long duration of exposure, the accumulated debris had covered the ablated spot can cause the refractive index seemed to be fluctuated in the range of 600 to 900 pulses.

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