Understanding the Multiwave Hybrid™ Processing of Polycarbonate

Material Description

Polycarbonate is a thermoplastic polymer that is optically transparent and electrically insulating. It is available in sheets with thicknesses of 0.020″ to 0.750″, and can also be extruded into shapes such as rods and tubes. It has higher strength and much better heat resistance than acrylic (PMMA). It is often used in the fabrication of electrical and telecommunications equipment because of its light weight, strength and thermal and electrical properties. It is used for light weight, shatter resistant windows. Polycarbonate can be readily coated with aluminum to form reflectors for lighting applications. Another major use is data storage in the form of DVDs and Blu-ray disks.

Laser Processing Observations

Polycarbonate sheets up to 1/8″ thick can be readily cut with a CO_2 laser. However typical laser cutting process leave a rough edge. Laser cutting also causes edge discoloration (see Figure 1a). The edge color can vary from yellow to dark brown depending on the laser cutting parameters. The surface roughness is due to melting of the polycarbonate during laser cutting. A smooth surface can be obtained by cutting with high peak power. For example, 150 watts at 50% power and 400 pulses per inch. This limits the edge heating, and produces a smooth surface as shown in Figure 1b. Although the edge is smooth, it is still discolored. The reason for the discoloration has been report as oxidation of the aromatic rings in the polycarbonate molecule. The edge discoloration issue appears to be endemic to polycarbonate, and to date no solution has been found.

a) b)

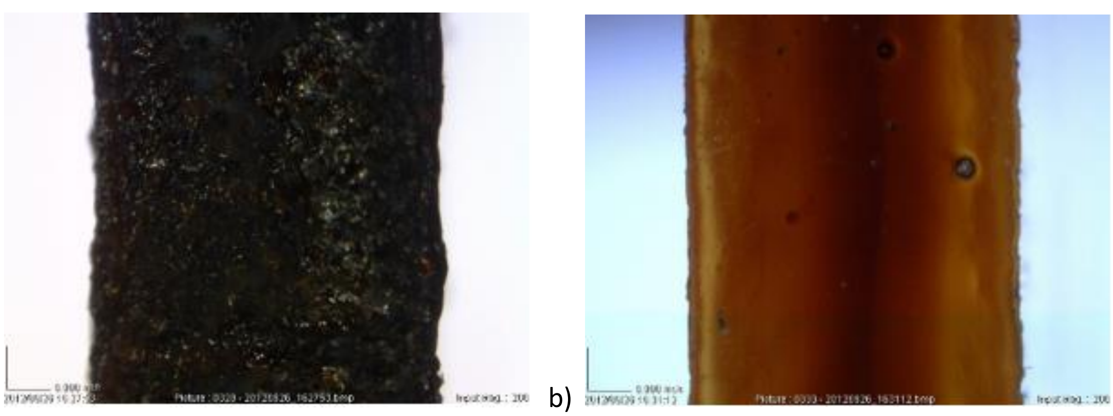

Figure 1. a) Typical laser cut edge showing rough surface and discoloration. b) A high peak power laser cutting process results in a smooth edge, but it is still discolored.

Polycarbonate can also be marked using either a CO_2 laser or a fiber laser. The CO_2 lasers produce a dark brown mark, while the fiber laser produces a black mark. Based on the polycarbonate absorbance spectrum shown in Figure 2, the CO_2 laser wavelengths (9.3 or 10.6 µm) are absorbed more strongly than the fiber laser wavelength (1.06 µm). This may explain the difference in marking color. The 1.06 µm wavelength beam penetrates more deeply into the polycarbonate creating a darker mark.

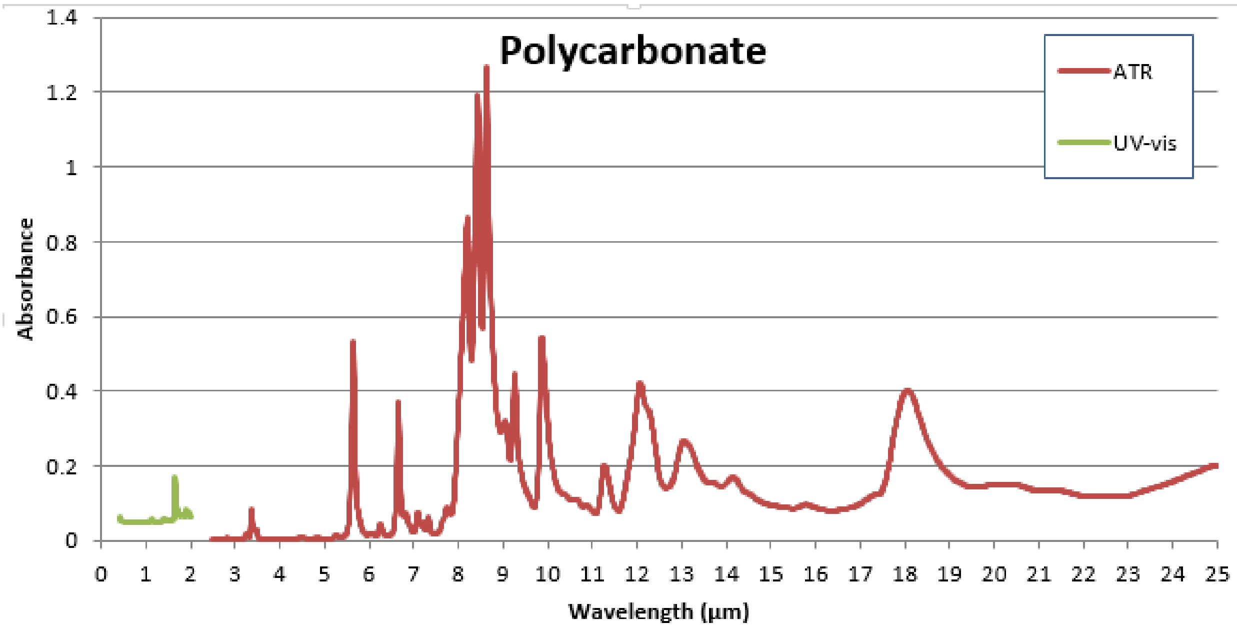

Figure 2. Optical absorbance spectrum polycarbonate.

Hypotheses Regarding Multiwave Hybrid Processing of Polycarbonate

The repeating unit of polycarbonate includes two aromatic rings as shown in Figure 3. FTIR spectroscopy studies of laser induced polycarbonate degradation have shown a decrease in aromatic groups coupled with an increase in oxygen content. This suggest that oxidation of the aromatic rings is responsible for yellowing of the material [1,2].

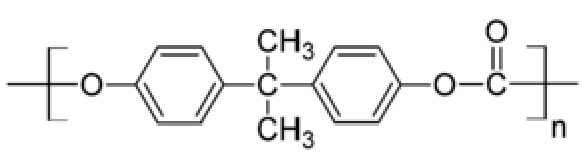

Figure 3. Repeating chemical structure unit for polycarbonate.

Polycarbonate absorbs infrared light very well, including the CO_2 laser wavelengths and the fiber laser wavelength. Therefore these lasers would be expected to contribute to yellowing of the edge. However polycarbonate is transparent to visible light. This suggests that combining a CO_2 laser with a visible laser, such as a 532 nm green laser, might produce a beneficial result. The CO_2 laser would be employed for the purpose of polycarbonate ablation to create the cut. The green laser would be added to simultaneously remove the yellowed portion of the cut edge. This wavelength would be absorbed by the discolored material, and with sufficient power it would be ablated away. Since the bulk polycarbonate is transparent to this wavelength, no new discoloration should occur.

Testing our Hypotheses for Multiwave Hybrid Processing of Polycarbonate

An initial test of our hypothesis that discolored polycarbonate can be removed using a visible laser can be done by sending a laser cut sample to a manufacturer of visible lasers for a demonstration. First cut a polycarbonate sample with a 10.6 μm CO_2 laser using the high peak power method described above. Then send the sample to a manufacturer of visible lasers such as the Quasar 532 – 75 from Spectra-Physics. Ask the company to develop their best process for removing the discolored material. They can experiment with parameters such as average power, peak power, repetition rate and angle of incidence. If this this test is successful, then we can begin looking into integration of a visible laser onto an XLS10MWH system.

Integration of a visible laser onto the XLS platform will require close work with engineering. We will need to determine whether or not appropriate multiwave optics can be developed to extend into the visible wavelength range. If not then a dual beam path approach would be necessary.

Once integration is complete, we can begin developing a single process of simultaneously cutting and removing the discolored material. The operating parameters of the CO_2 laser and the visible laser should be optimized statistically using the MATRIX software. In addition, the visible beam diameter should be considered as a variable with respect to the CO_2 beam diameter.

Two other factors should be considered. First, since oxidation of the aromatic rings is the reported cause of yellowing, an inert environment should be considered. This could be done with a nitrogen gas assist using the high pressure cone. Second, using a UV stabilized polycarbonate may help to limit the yellowing of the polycarbonate.

References

1. E. Apaydin-Varol, S. Polat and A. Putin, Thermal Science, vol. 18, no. 3 (2014) pp. 833 – 842.
2. J. Rabek, Polymer Photodegradation: Mechanisms and Experimental Methods, Springer (1995) p. 282.