PULSED UV CURING

Effective Technology for Blu-ray and HD Disc Process Development

Workshop: May 12, 2005

Presented by

Louis Panico, CEO

About Xenon – Application Segments

- Pulsed UV Lamps

- Pulsed UV Curing Systems

- Pulsed UV Sterilization Systems

Workshop Topics

- Understanding UV Sources
- Attributes of Mercury UV and Pulsed UV
- Benefits of Pulsed UV Curing for HD and Blu-ray Disc
- Achieving Lower Costs with Pulsed UV
- Non-Contact UV Surface Treatment of different materials
- Applications of Pulsed UV Curing in the Production of DVDs
- Pulsed UV in Emerging Optical Disc Technologies

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Understanding UV Sources

- Basic methods for the generation UV
  - Continuous
  - Pulsed

- Sources of plasma-generated UV radiation
  - Electric arc
  - Mercury lamp
  - Pulsed lamp

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Some Characteristics of Mercury UV Lamps

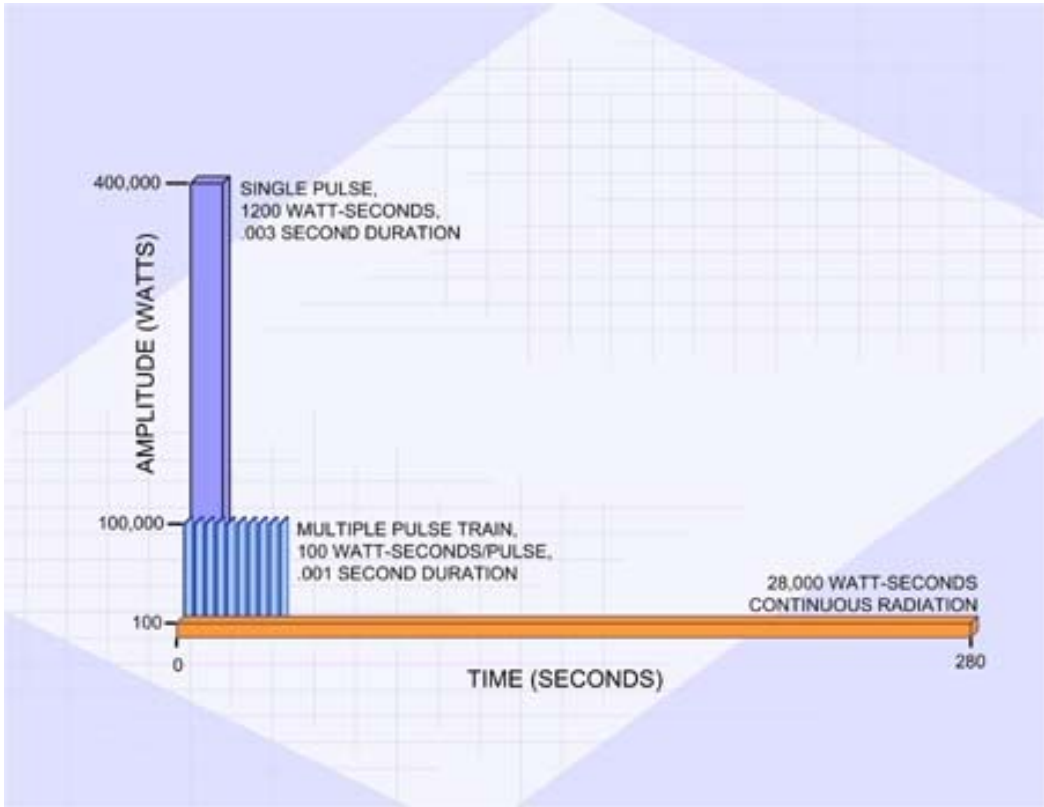
Before a mercury lamp can convert electrical energy to light, the liquid mercury must be converted to a gas. To accomplish this conversion, the lamp needs to be elevated in temperature. The quantum yield of the mercury lamp is zero while the mercury is in a liquid state.

- The mercury lamp is intrinsically a heat generator. The heat results from both the elevated temperature of the lamp and the IR radiation.
- The mercury lamp requires substantial "warm up" time making it inefficient for high speed start-stop applications.
- The mercury lamp is limited in geometric designs
- The mercury lamp has discrete line spectrum
- The mercury lamp emits ***low peak power***, continuous radiation
- The mercury lamp machine integration is complicated at high power
- The mercury lamp contains a hazardous element -- ***mercury***….

Some Characteristics of Pulsed UV

- The pulsed UV lamp is ***mercury free*** and requires zero warm up.
- Pulsed UV is intrinsically a low temperature technology.
- Pulsed UV is inherently a flexible technology and can be configured for new and changing formats.
- Pulse UV generates wideband radiation – 50 nm to 5 microns and is especially rich in the UV region
- Pulsed UV emits at very ***high peak power*** .. Up to 100,000 the intensity of the sun on earth.
- Pulsed UV systems are modular – integration is uncomplicated.
- Pulsed UV is operator safe and environmentally benign – no VOCs.

Comparison of Pulsed UV vs. Mercury UV

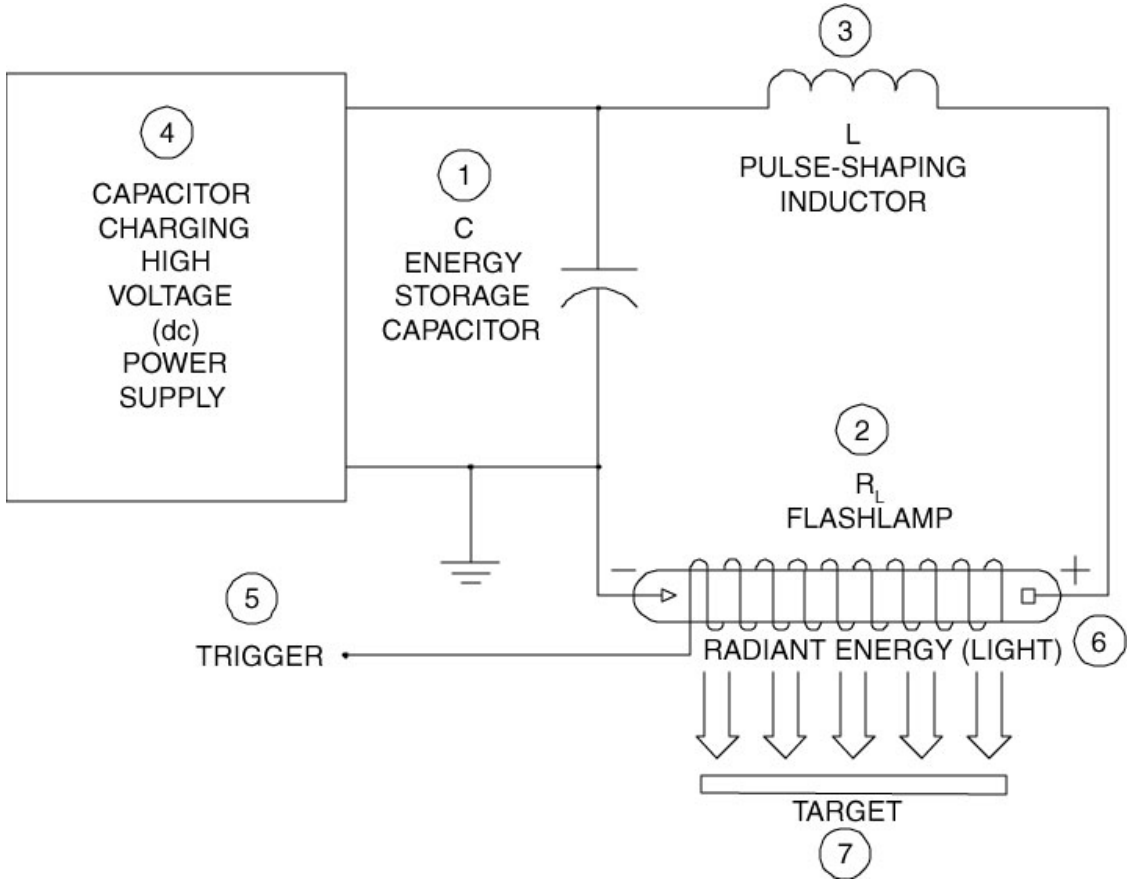


Pulsed UV is illustrated in a single pulse and burst mode

Pulsed UV System Consists Of.....

- Pulsed UV lamp – the heart of the system
- Inline process control
- High efficiency power supply
- Energy storage element
- Pulse Configurator
- High speed electronics trigger system
- UV optics

Block Diagram
- Pulsed UV System



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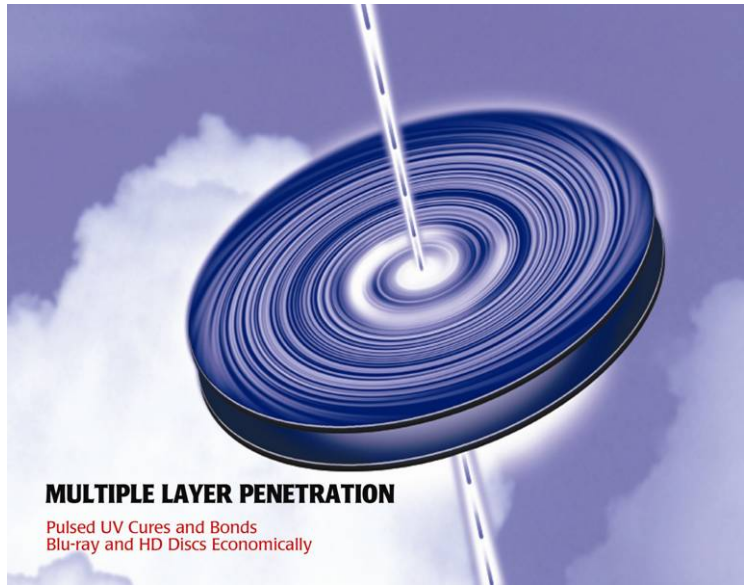


Benefits of Pulsed UV
- for HD and Blu-ray Disc Processing

1. **High Peak Power**
   - deep penetration of multiple and thick layers
   - complete hard coat cures
   - much Less power required
   - shorter cure times, less energy
2. **Instant On/Off (no lamp warm-up required)**
   - energy delivery flexibility
   - simplified handling system
3. **Spectrum flexibility**
   - tuned spectrum to match chemistry
   - set spectrum for tilt management
4. **Low Heat Technology**
   - less heat to DVD and handling equipment

Benefits of Pulsed UV (continued)

5. **Multi shaped lamps**
   - lamp shape matching optical “footprint”
6. **Dual lamps from single system**
   - ease of tilt management at low cost
   - production flexibility
7. **Ability to overcome oxygen inhibition**
   - fast complete edge curing
8. **Easy to integrate in automated machines**
   - no rotation, water cooling, or mechanical shutters required
   - no cooling of reflectors and/or handling equipment required
   - no special lamp disposal handling required due to mercury in lamps
   - no special edge curing optics required
   - no need for tolerance requirements on coating thickness and uniformity

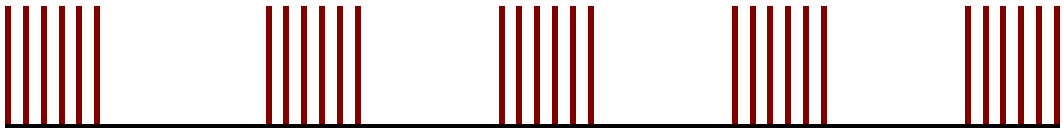
Results = High Quality HD and Blu-ray Disc Curing

Deep Penetration of Polycarbonate Layers

- Tests at WAMO in year 2000 confirmed the benefits of high peak power for high quality, mass production of DVDs.
- The benefits of the high peak, penetrating power included faster bonding and more reliable cures with significantly less power required.

The automated DVD Bonder at WAMO used pulsed UV, high peak power tests in the year 2000.

Instant On/Off for start-stop-start

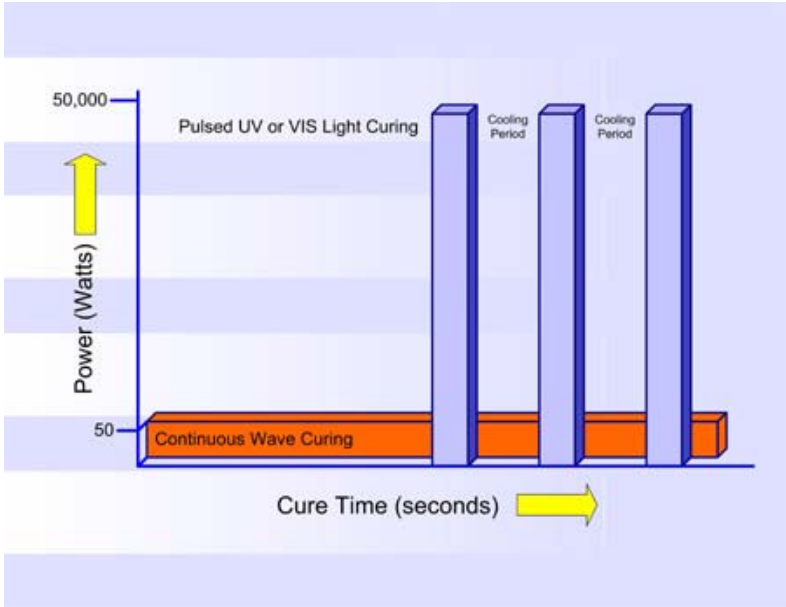


Example of instant on/off control of UV lamp.
6 UV pulses, sequenced to allow placement of DVD disc

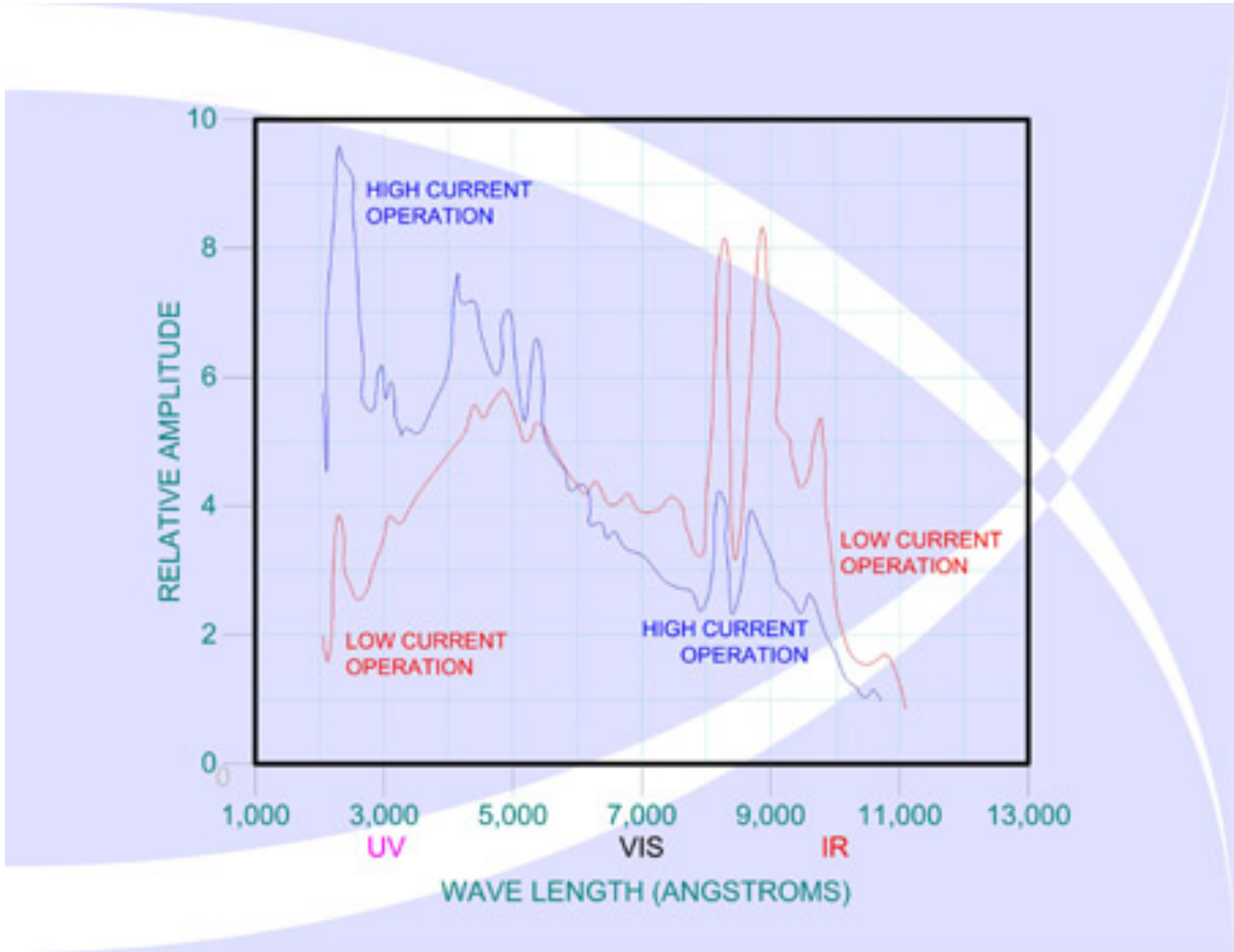
Limitless Possibilities

Why There Is Low Heat Transfer to Substrate with Pulsed UV

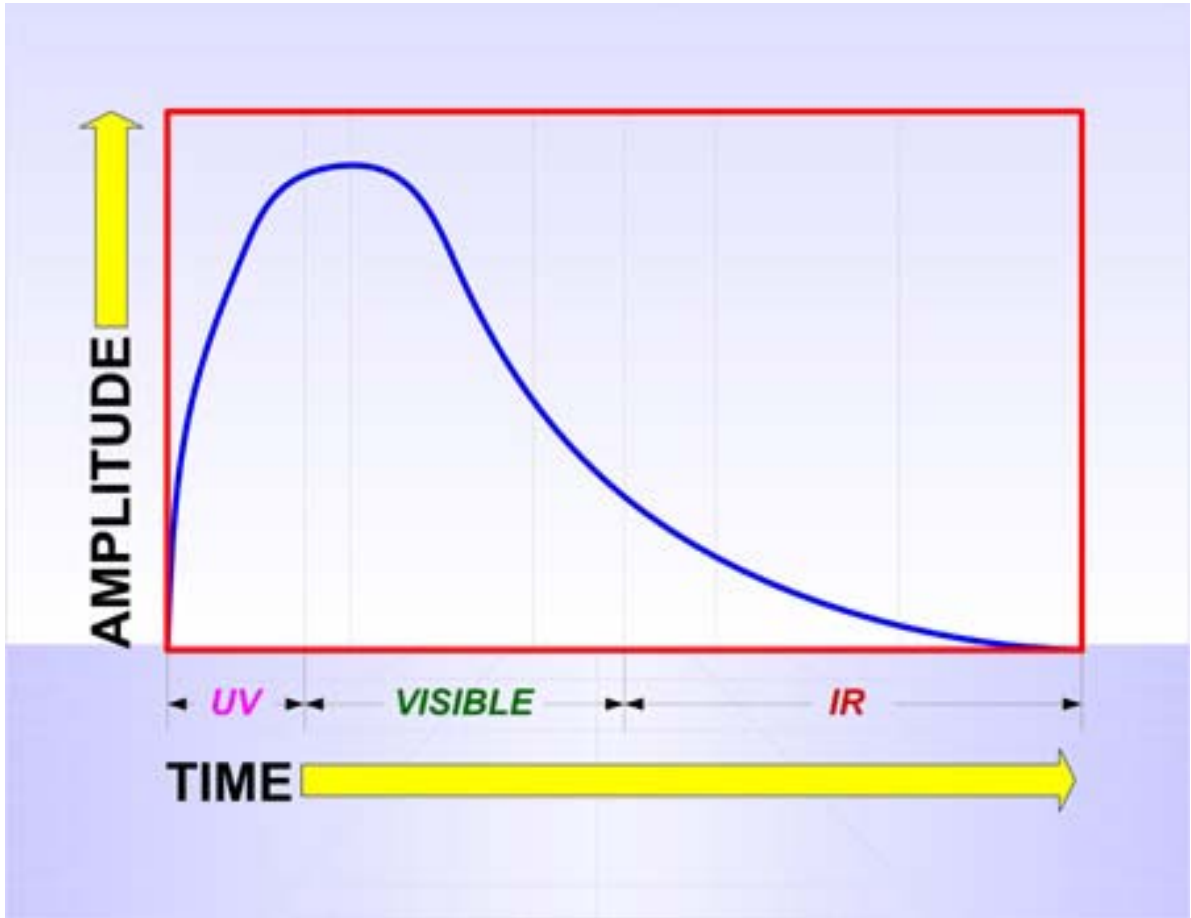
- High pulse ***peak*** power reduces the need for high average power
- Lamps are instantly turned on/off during cure time – and remain off while disc is being positioned
- Short-duration pulses (168 µs)
- Cooling zone between pulses
- Xenon lamps do not have to run at elevated temperatures for operation
- Low IR spectrum content



Flexible Pulsed Light Spectrum



Single Pulse Spectrum Flexibility



Flexible Lamp Geometries

Multi-shaped lamps illustrating flexibility of pulse UV lamp design

DVD Edge Curing – It's not a problem

Spiral lamp, designed to match DVD geometry, provides superior, repeatable edge cures

*** Patent-Pending**

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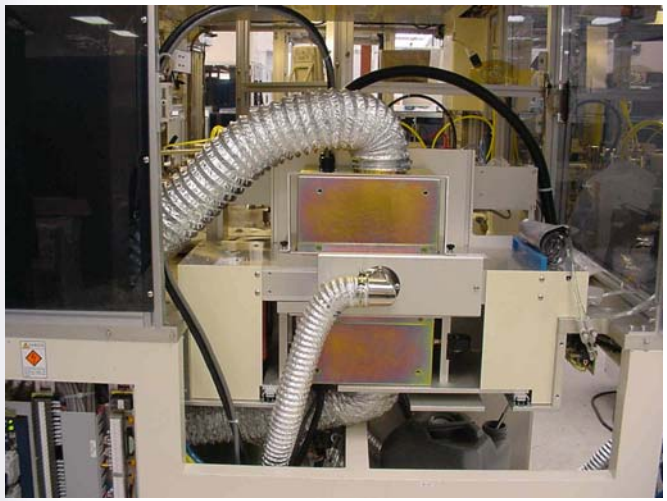
Tilt management

- using energy control and dual lamps



Pulsed UV lamp housings (top and bottom) sandwich the DVD for tilt management

Pulsed UV dual lamps operated from a single power supply and controller

- Patent-Pending

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How do we achieve lower cost?

- High peak power significantly reduces average power
- High peak power reduces photoinitiator required
- Dual lamp tilt management results in higher yields
- Instant On/Off provides UV only during cure time resulting in lower power and less heat
- One dual lamp system replaces two mercury systems
- Dual lamp provides top down, bottom up, or both curing allowing multiple formats on one machine

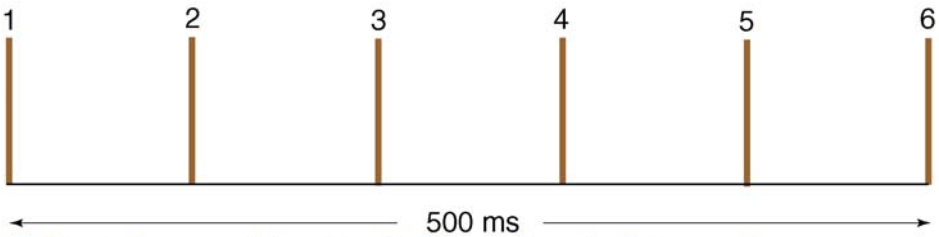
Pulsed UV-Curing Adhesives and Lacquers

Matching the pulsed UV benefits of peak power, pulse configuration and spectrum flexibility to the photochemical requirements of the formulation.

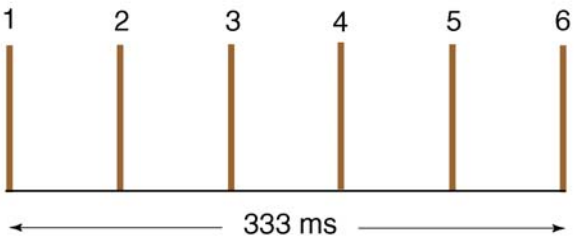
Some of the organizations involved in this effort include:

Adhesives and Lacquers
Borden Chemical, Inc
Dainippon Ink and Chemicals, Inc.
Eques Coatings
Sony Chemical Corporation

Achieving Faster Cure Time
- Example when 6 pulses are provided



RC-801 System with 2000 J/s Power Supply@10 pps Rate
TOTAL ENERGY=1242 Joules (207 Joules/pulse x 6 pulses) in 500 ms



RC-801 System with 3000 J/s Power Supply@15 pps Rate
TOTAL ENERGY=1242 Joules (207 Joules/pulse x 6 pulses) in 333 ms

In this example, a lamp trigger rate of 15 pps achieves a shorter cure time (333 ms versus 500 ms) compared to a 10 pps rate. The total energy delivered to the substrate remains constant (1242 Joules).

Achieving Faster Cure Time

Format	Cure Time @ 10 PPS	Cure Time @ 15 PPS
DVD-5	600 ms	470 ms
DVD-9	1200 ms	800 ms
DVD-10	1400 ms	900 ms
DVD-14	1200 ms	800 ms
DVD-18	1200 ms	800 ms

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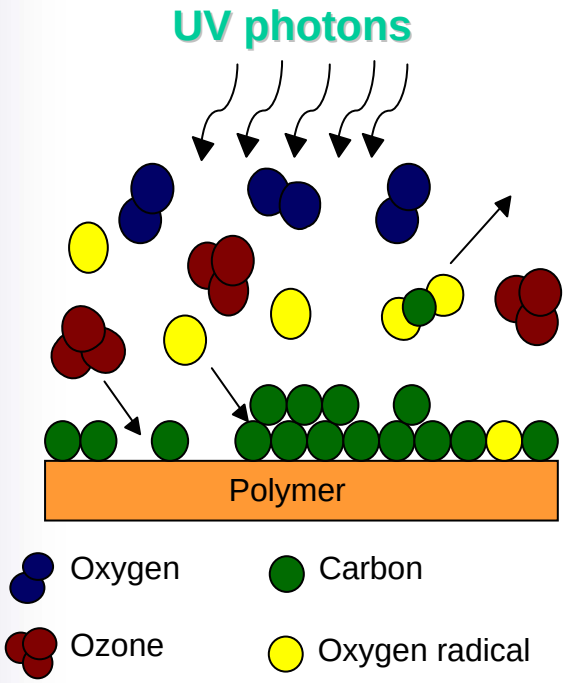
Non-Contact Surface Treatment Of Polycarbonate

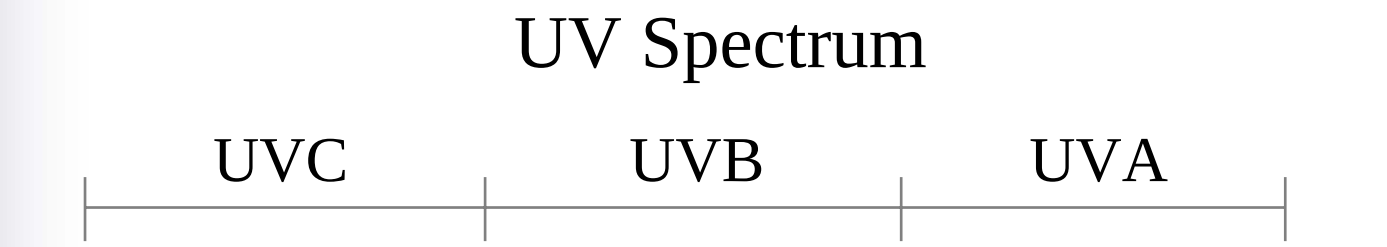
- Adhesive performance depends on quality (cleanliness and surface energy) of substrate (adherent) surface
- Disadvantages of existing surface pretreatment methods such as plasma, flame, corona and solvent washing:
  - Labor intensive
  - Time consuming
  - Damage to the adherent surface
  - Emission of volatile organic compounds (VOCs)
- UV treatment studies at Michigan State University on polymers used as matrices for polymer composites

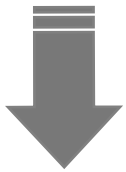
Parameters for Pulsed UV surface treatment - comparison of methods



Intensity of Pulsed UV
Ozone concentration
Humidity
Substrate temperature
Nature of gas flow
Pulse configuration
Exposure time
Pulse recurrence frequency
Nature of the substrate

Pulsed UV Spectrum and Interactions





$$O_2 \xrightarrow{185\ nm} O^* + O^*$$

$$O_3 \xrightarrow{254\ nm} O_2 + O^*$$

Interactions with surface

- evaporate water
- oxidize organics
- add functional groups
- increase surface energy
- change morphology
- degrade surface
- evolve CO_2, water

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Materials Studied at Michigan State

- Thermoplastic polyolefin (TPO)
  - Reactor Grade (RTPO)
  - Mechanical grade (MTPO)
- Sheet molding compound (SMC)
  - Regular (SMC1)
  - Toughened (SMC2)
- Polyphenylene Sulphide (PPS)
  - White (PPS1)
  - Black (PPS2)
- Polypropylene (PP)
- Polybutylene terephthalate (PBT)
- Bulk Molding Compound (BMC)
- Diene rubber (DR)
- Ethylene Acrylic Rubber (EAR)
- Polymethyl methacrylate (PMMA)
- Vinyl Ester (VE)
- Polycarbonate (PC)
- Bexloy (Ionomer) Composite

Polymer Surface Modifications - by Pulsed UV Treatment

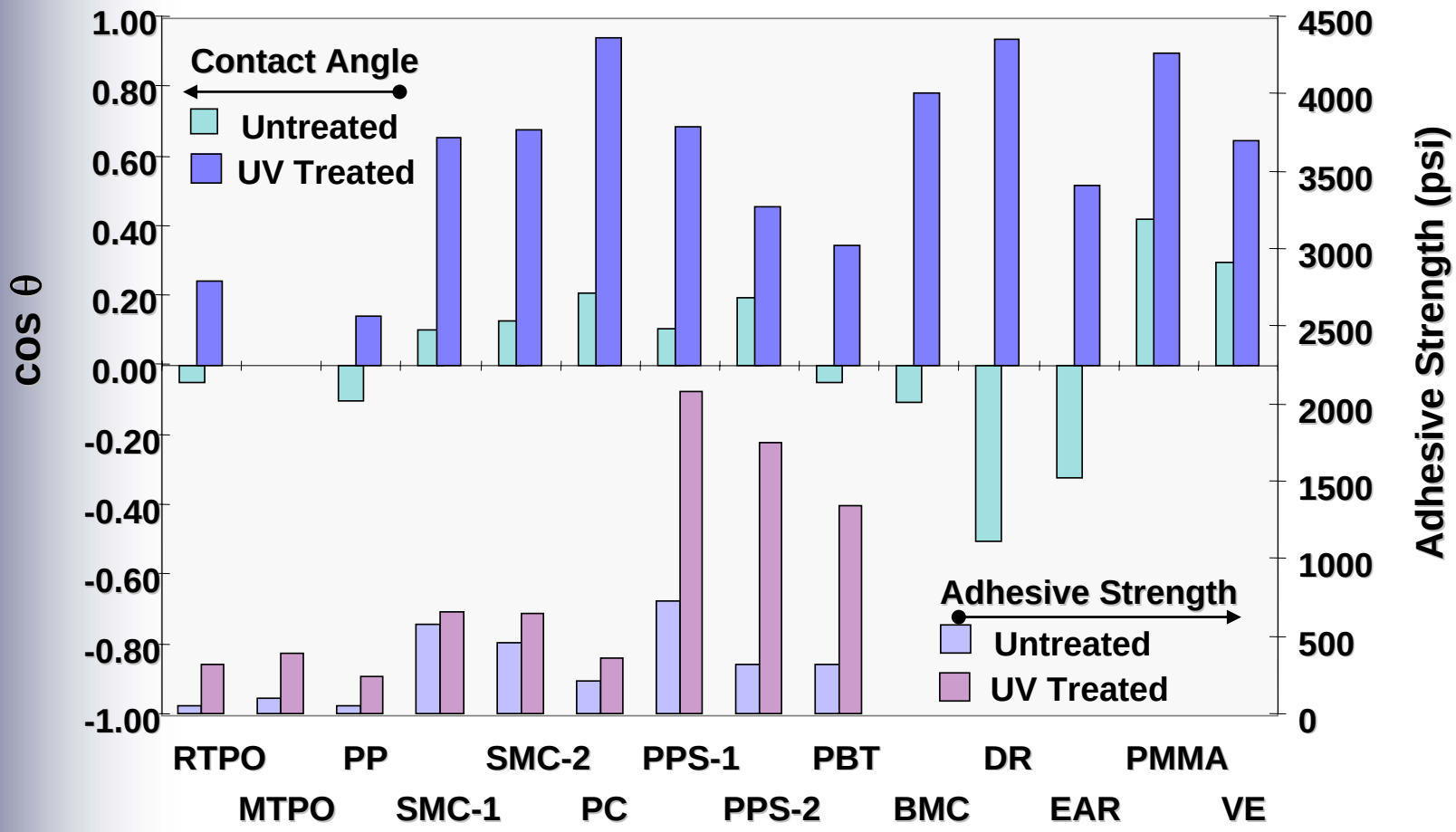

Chart provided by Prof. Lawrence Drzal, Composite Materials & Structure Center, Michigan State University

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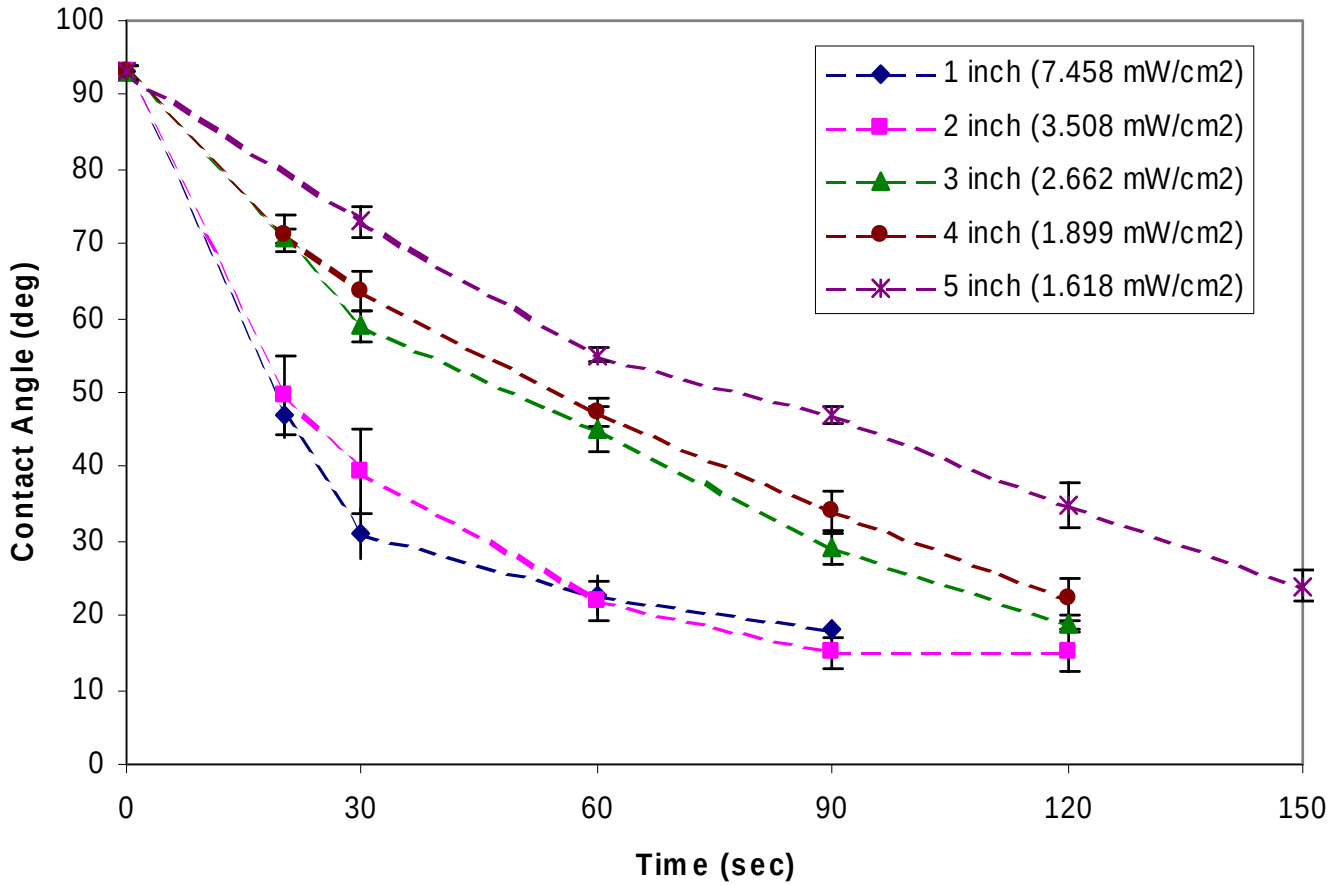
Effect of Irradiant Power & Exposure Time

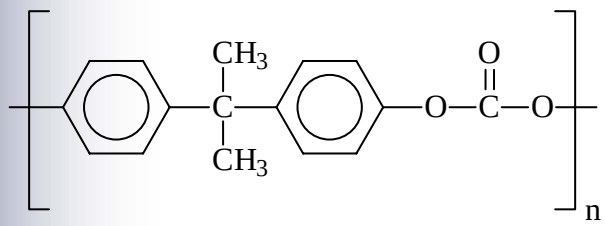
UV Irradiant Power varied by changing distance between lamp and sample.

Power x Time = Irradiant Energy

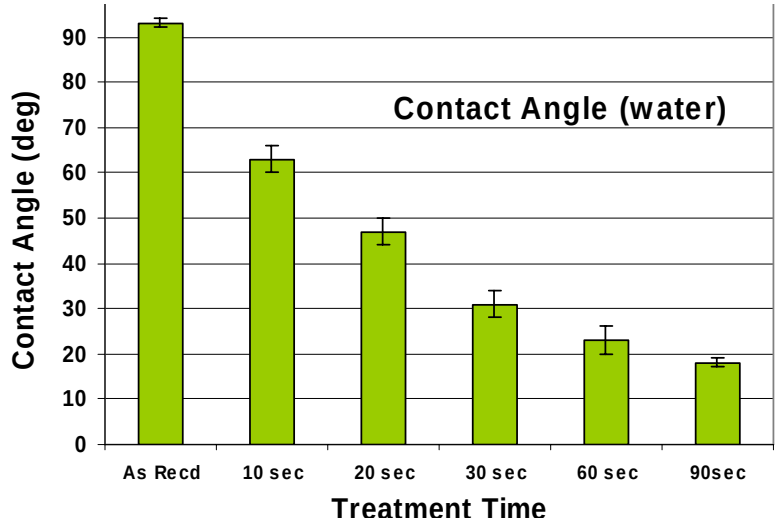


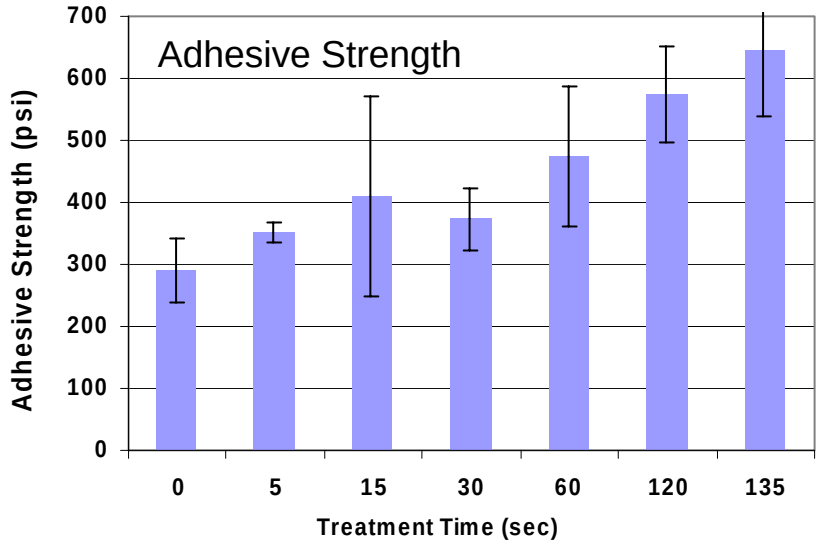
Effect on Polycarbonate

- Polycarbonate (GE 8040) 175μm thick film.

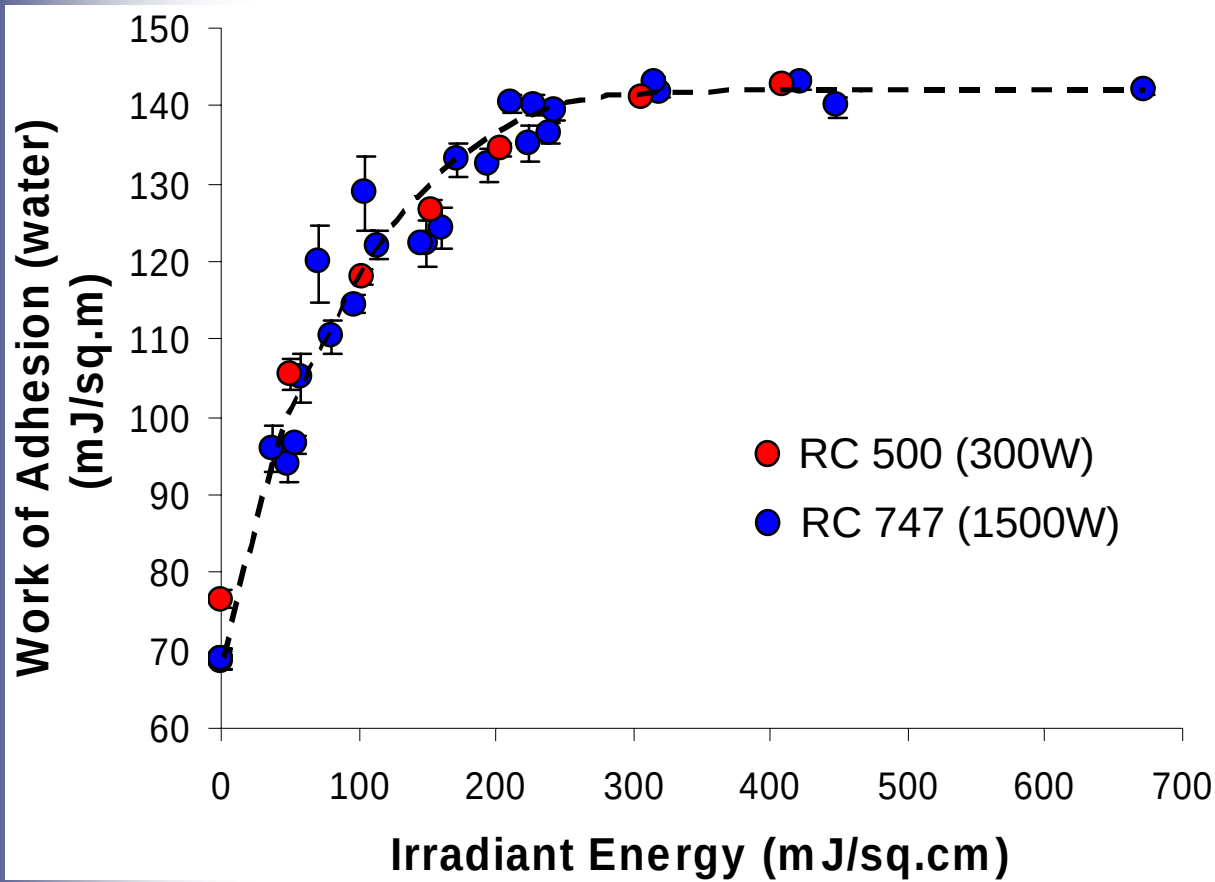


- Pulsed UV treatment causes favorable changes in wettability and adhesive strength.





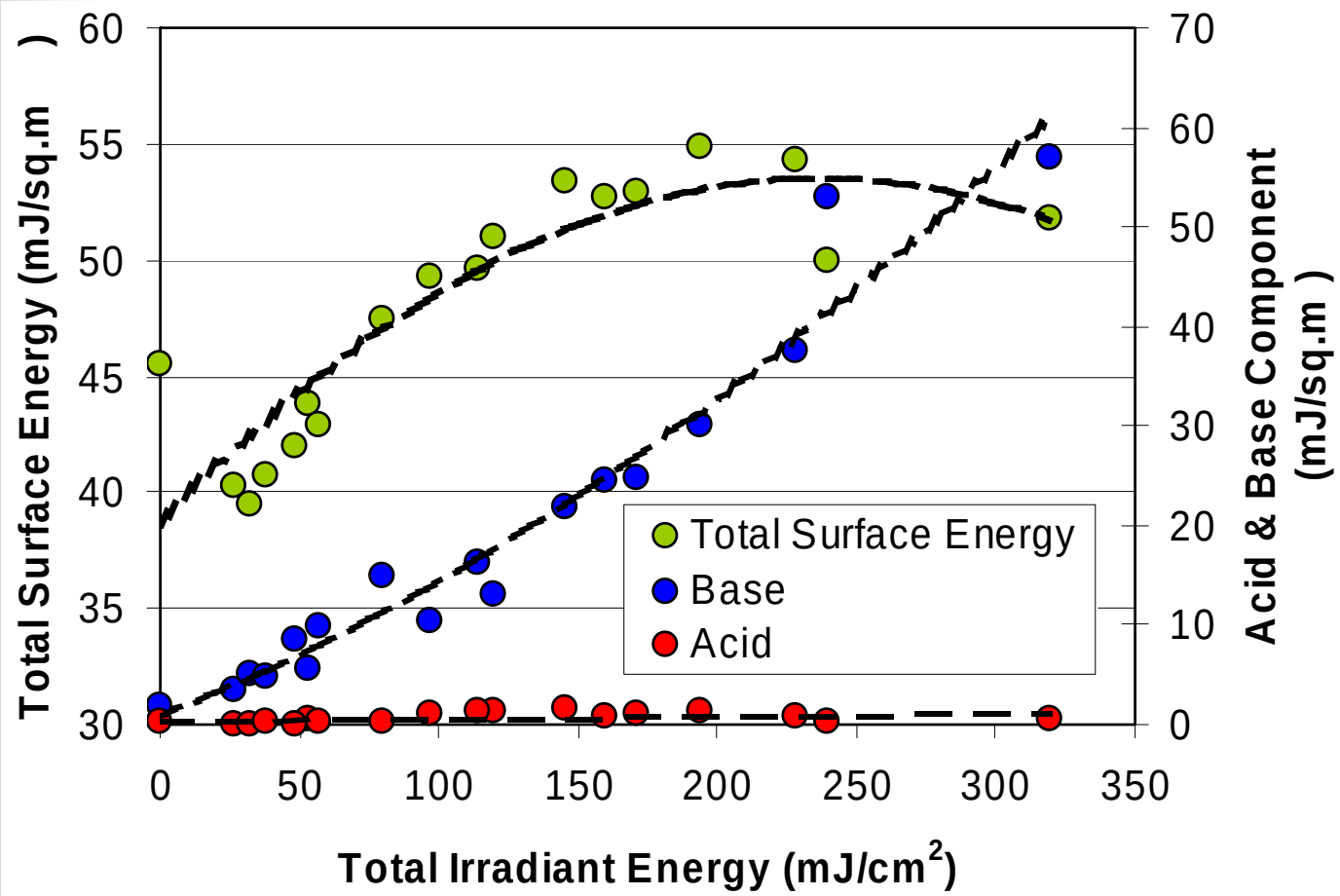
Work of Adhesion vs. Irradiance



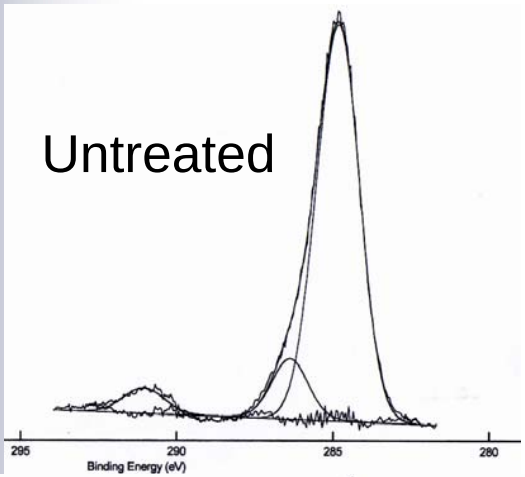
- Work of adhesion is independent of both irradiant power and exposure time.
- Dependence is only on the total irradiance.
- *Long treatments at low power and short treatments at high power yield identical results.*

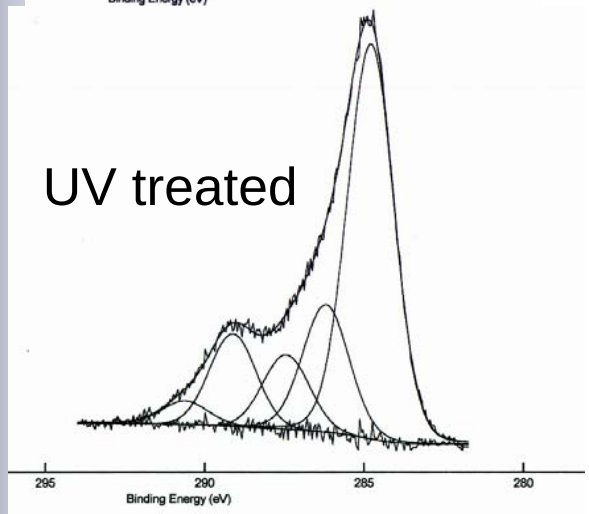
Surface Energy (Acid-Base Model)

Change in surface energy depends on total irradiant UV energy



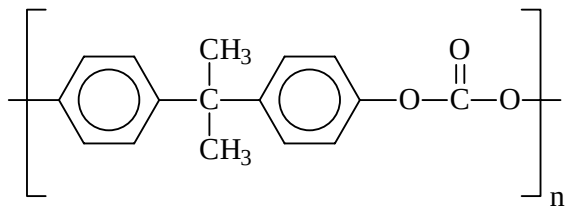
Deconvoluted C1s Curve Fit



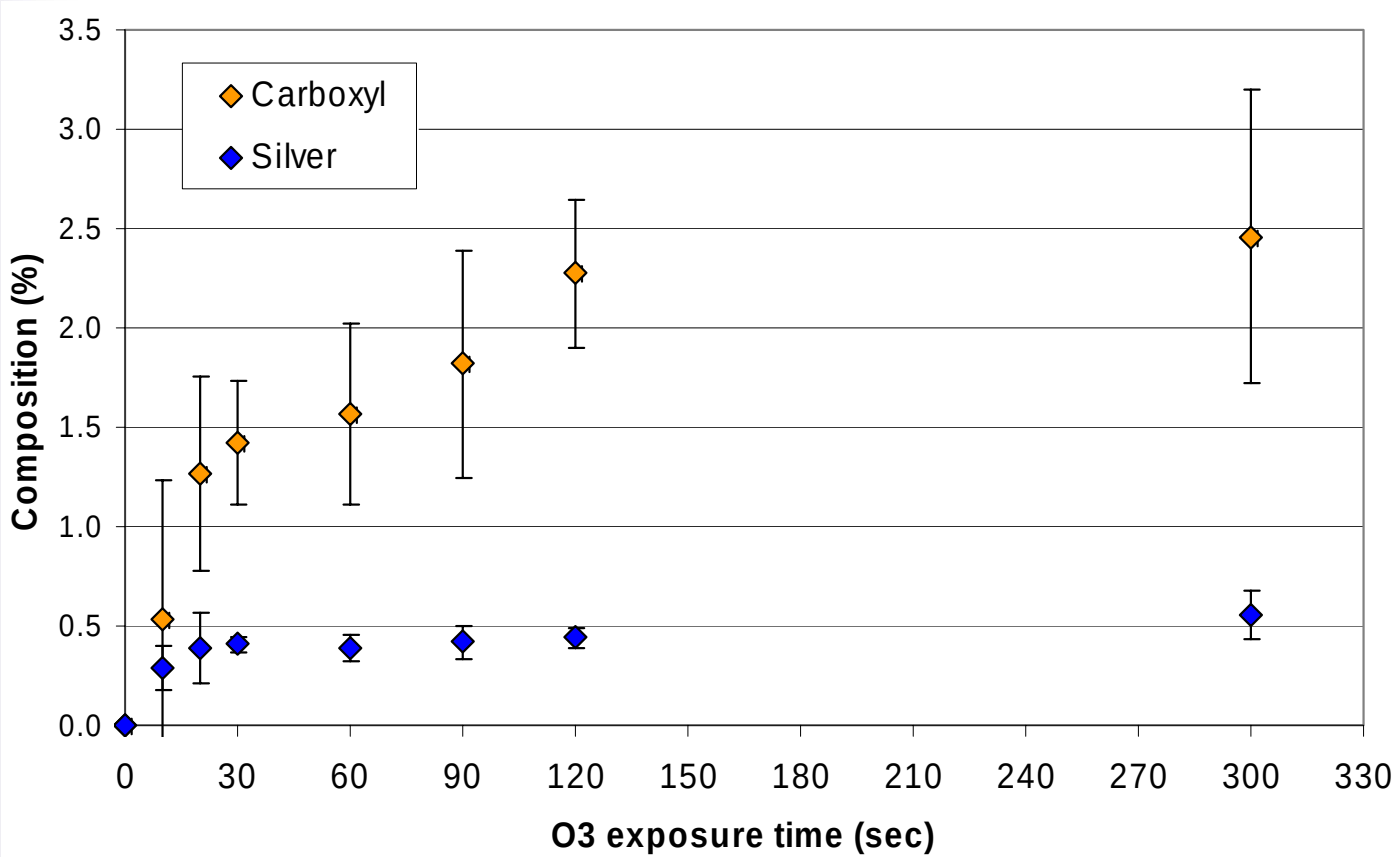


Irradiance (mJ/cm^2)	C-C	C-O	C=O	O-C=O	Carbonate
0	83.4	11.4	0.0	0.0	5.1
27	77.8	16.9	1.1	1.1	3.1
53	71.6	15.0	5.1	4.3	4.0
80	67.0	17.0	6.1	6.4	3.5
114	60.6	20.7	7.7	7.7	3.4
160	61.2	18.9	8.3	9.0	2.7
200	56.6	20.1	10.3	11.4	1.6
228	53.0	21.1	10.1	13.4	2.5

- Decrease in carbonate peak suggests UV induced chain scission with cleavage of carbonate bonds in the polymer backbone.



Surface composition of silver and carboxyl groups in AgNO3 derivatives Pulsed UV treated Polycarbonate



Comparison of Surface Treatments

	Conventional Surface Treatments (Flame, Corona, Plasma, Chemical)	UV Surface Treatment
Current Status	Flame, Corona and Chemical Wash are mainstream surface treatment technologies. Plasma - limited acceptance.	Developing technology - Equipment manufacturing base exists.
Environmental Impact	Chemical – VOC emission, waste disposal. Corona – High levels of ozone produced. Flame – Greenhouse gases, organic fuels.	Very low levels of ozone produced in contained environment.
Ability to Treat Complex Geometries	Flame, Corona and Plasma Treatments have severe limitations in treating complex geometries.	Line-of-sight treatment. Potential to treat complex geometries is excellent.
Treatment Time	Corona, Flame – Very fast treatment times Chemical, Plasma – Moderate treatment times	Fast treatment times (Time scales inversely with lamp power)
Hazards	Chemical – human exposure, waste disposal Corona – very efficient Ozone production	UV protection for humans
Cost	Corona, Flame, Chemical – Inexpensive Plasma – Expensive	Inexpensive
Suitability in Manufacturing Environment	Corona, Flame – Web treatment applications. Removal of process gases required. Chemical – Adverse environmental impact, hazardous. Plasma – Unsuitable for large scales.	Excellent suitability for all applications – flat, complex geometries, large scale. Minimal hazards – UV protection, Removal of low levels of ozone required.

SUMMARY

- Pulsed UV Polycarbonate Treatment Process

- An environmentally benign, non contact, surface pretreatment process for treating flat polycarbonate substrates.
- Cleans any polycarbonate surface including removal of mold releases
- Increases wettability and improves adhesion of adhesives and lacquers to treated polycarbonate surfaces
- Environmentally benign since it does not create or use VOC′s or create suspended airborne particulates
- A process competitive with existing processes (flame, corona and plasma).
- The process is low cost and high speed with current pulsed UV system designs

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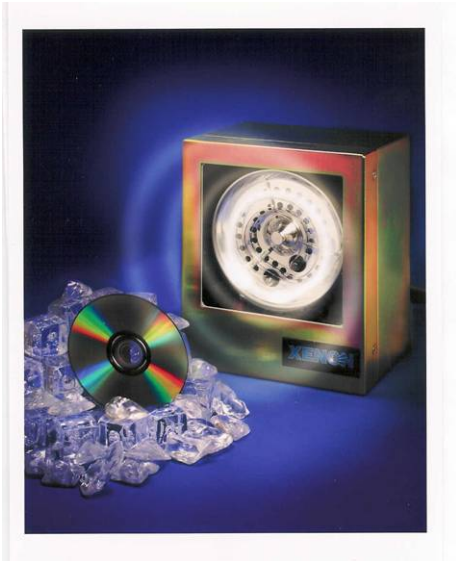


Application of Pulsed UV Technology - DVD Bonding at Cinram

Automated DVD Bonder manufactured by Origin Electric Co., Ltd.

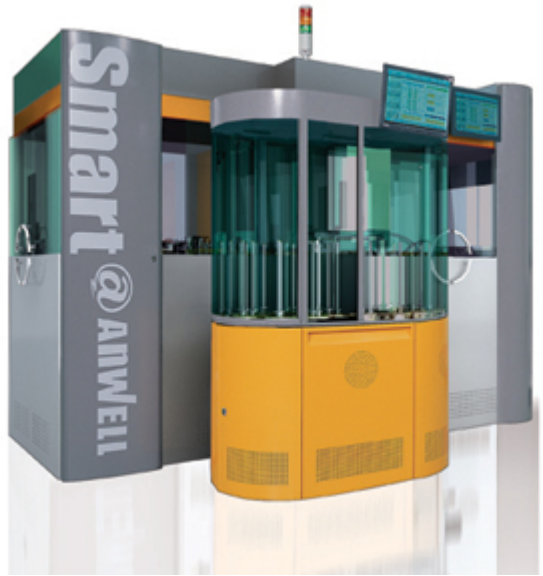
Application of Pulsed UV Technology - DVD/CD Finishing Machine Model SQ-02

M2 Engineering AB

- SQ2 features integration of all components for buffering, sputtering, spin coating, curing, inspection and restacking of CD and DVD discs in one machine.
- SQ2 features M2's unique CenterBond™ technology, which allows for bonding all the way to the center of the disc. The SpinCure™ technology creates uniform bonding layers.

Application of Pulsed UV Technology - Anwell SMART HD-DVD Replication Line

- **Fastest cycle time in the world – 2 sec**
- **Cold Flash UV system**
- **One touch machine setup**



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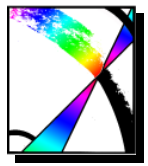
Aprilis Using Pulsed UV for Holographic Technology



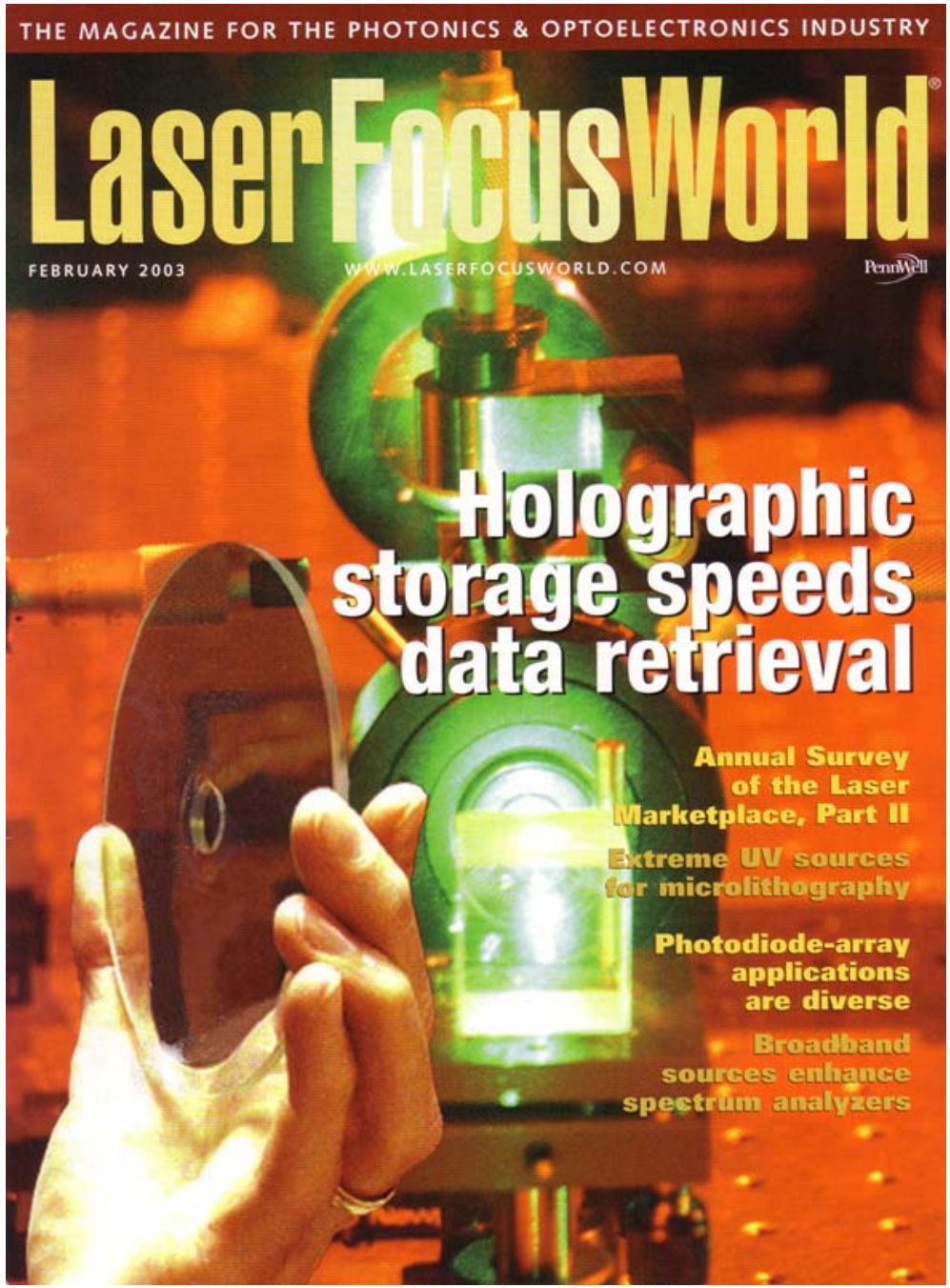
Aprilis

Data Storage Devices based on holographic technology

Graphics for the Play Side of Optical Media

Aprilis

www.Aprilisinc.com



Spectra Systems
CORPORATION

MediaCoat™
Graphics on the Play Side of Optical Media

A *patent-pending* marking technology for the *play side* of optical media.

Unlocks the unused, play side surface for:

- **Advertising**
- **Promotion**
- **Cross-marketing**
- **Content information**

Compatible with all formats, including:

- **Software CD-ROM**
- **Video DVDs**
- **Music CDs**
- **Double Sided DVDs**

How does MediaCoat work?

Color forming layer spin coat applied and UV cured

Graphics formation via Photo-Mask exposure

Protective layer spin coat applied and UV cured

Optical inspection

Conclusion

- A proven history of higher yields and lower costs for DVD bonding
  - Over 1,400 units operating in optical disc manufacturing.
  - Over 5 years of operation at major world wider replicators.
- Key attributes for DVD bonding include:
  - Elimination of heat-induced damage to the disc.
  - High peak, ***penetrating energy*** for efficient faster cures.
  - Ability to switch lamps on and off without warm-up.
  - Lower cost, faster curing adhesives and lacquers.
- Simplicity: No disc rotation, shutter, or water cooling required.
- Operator safe and and environmentally benign mercury free lamps.
- Pulsed UV is a ***flexible technology*** that can help meet today's needs for ***cost reduction*** and new technology needs for process solutions in holographic storage, playside graphics, limited play DVD, HD and Blu-ray.

Q & A

UV Curing Choices

The Brute Force of Mercury CW?

or the sophistication of Pulsed UV?