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TECHNOLOGIES






Excelitas Technologies®

Improved Surface Cure with UVC LED

Mike Kay

Director of Product Management, OmniCure®

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Who We Are

- Lumen Dynamics was acquired by Excelitas Technologies Corporation in November 2013
- Excelitas has over 5,500 employees worldwide
- Global network of design and manufacturing locations in the Americas, Europe and Asia
- Design and creation of innovative UV curing solutions since 1984
- Over 35,000 UV curing systems currently being used in more than 50 countries
- Lamp and LED UV systems

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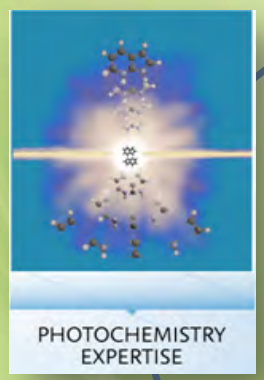
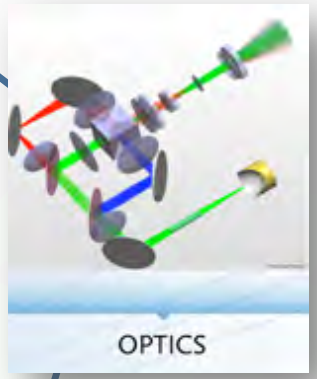
LUMEN DYNAMICS
PUTTING YOU IN CONTROL

OmniCure®
UV Curing • In Control

Technology Required for a Curing Process



UV Curing Process



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UV LED for Curing Applications

- UV LED curing systems have many functional advantages over lamp-based systems
  - Longer life, reduced energy, lower heat, lower maintenance, instant on/off, Hg free
- Formulation modification has enabled the use of many UV LED curable materials in commercial applications
  - Digital print, electronics assembly, optical bonding, medical device manufacture …

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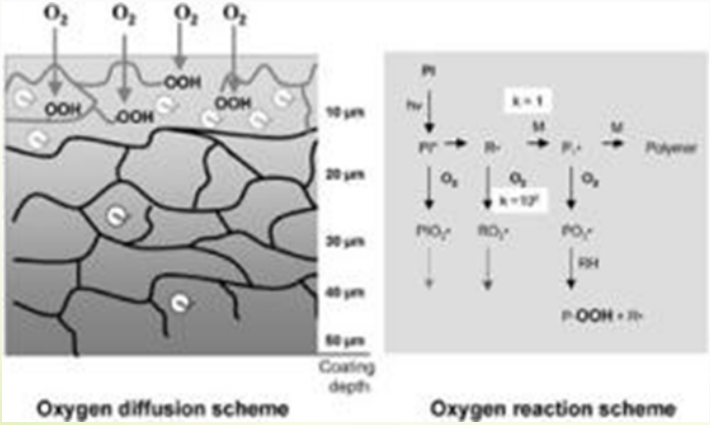
Surface Cure Remains a Challenge

- Free radical adhesives are susceptible to curing with a tacky surface when exposed to air (oxygen inhibition)
- Current techniques for improving surface cure
  - Formulation modification
  - Inerting (gas, wax, film)
  - High irradiance curing
  - Exposure to short wavelength UV



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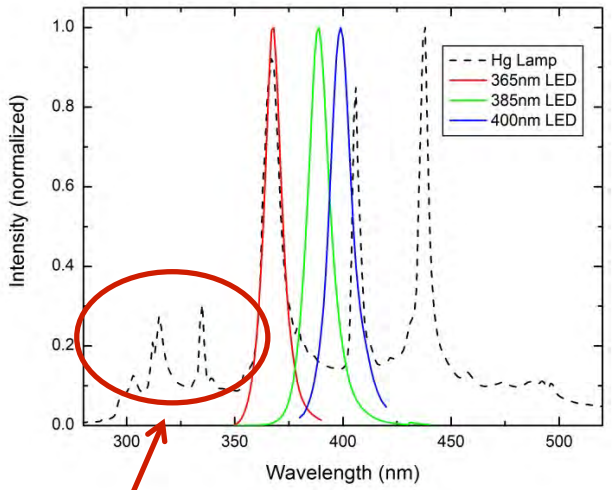
Is LED an Option for Surface Cure?

- We know short wavelength UV is useful for improving surface cure
  - < 350nm is required
- Commercially available UV LED curing systems currently do not cover the UVC spectrum
- UVC LEDs now available from multiple manufactures
  - Opportunity to benchmark technology



Current LED curing solutions lack UVC

Post cure or in line exposure to deep UV LEDs is an attractive solution to achieve surface cure taking full advantage of LED benefits.

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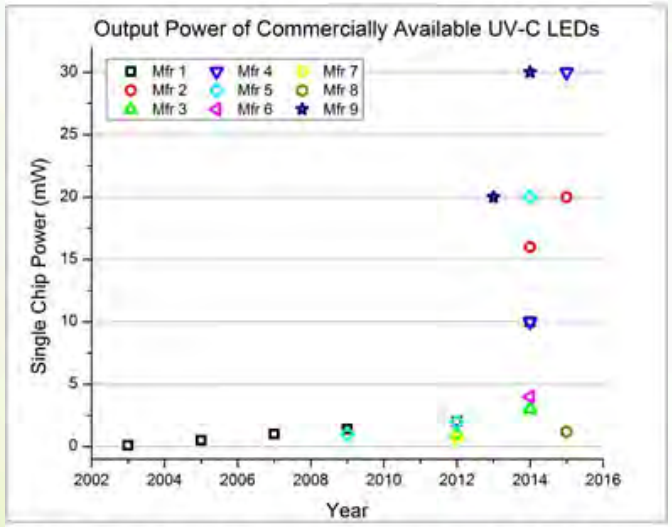
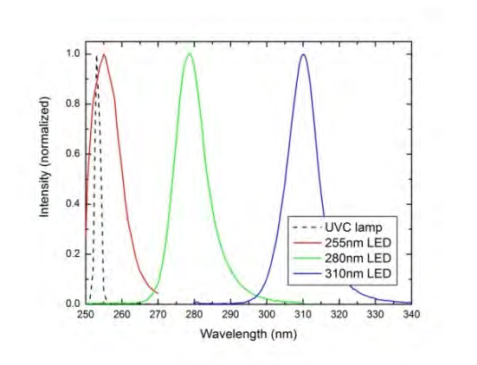
Evolution of UVC LEDs

- LED efficiency and lifetime continue to improve at a steady rate
- Technology breakthroughs 2014/2015
  - Increased R&D spending
  - Many new deep UV manufacturers
- Multiple wavelengths available
  - 285nm initially selected



* Source: AquiSense Technologies, July 2015



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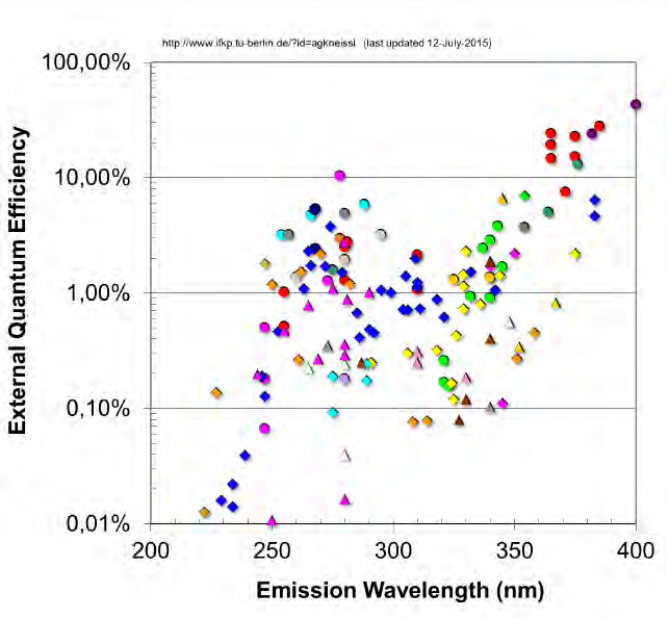
The UVC System Challenge

- UVC die limitations
  - More heat than light
    - (<10% external quantum efficiency)
  - Greater non-radiative recombination associated with defects in the die
  - Difficult to extract light
- System designer must evolve
  - Cutting-edge LED packaging materials & methods
  - Innovative thermal management techniques
  - Advanced light collection and delivery optics
    - every photon counts



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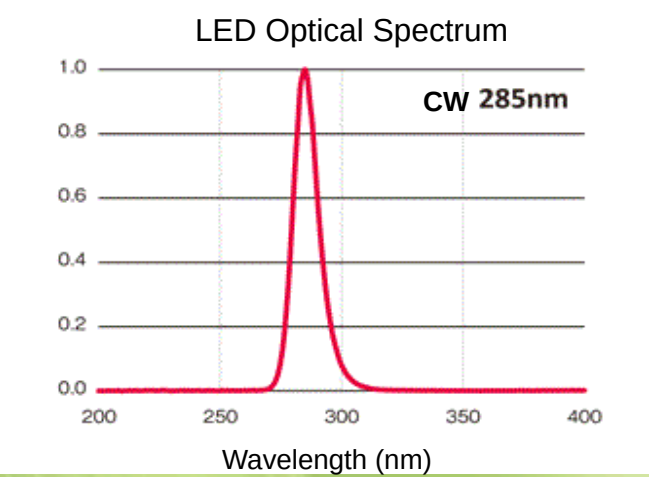
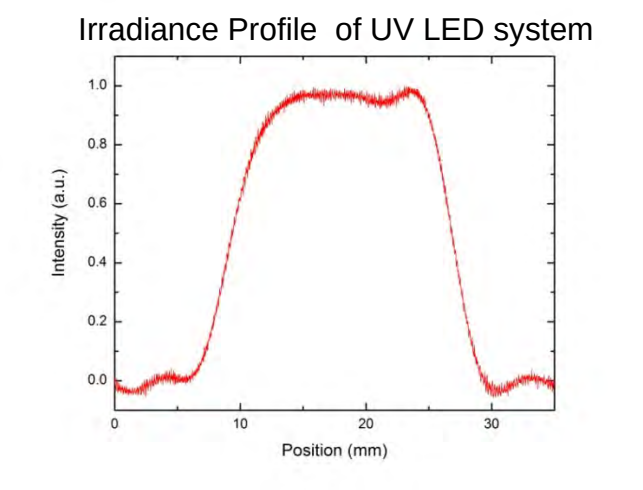
First Cure Trials Performed





- 285nm LED array constructed
  - Very low irradiance achieved: <100mW/cm^2
- Multiple adhesives & conformal coatings selected for trials
- Samples exposed to UVA/UVV LED radiation with a UVC LED post cure

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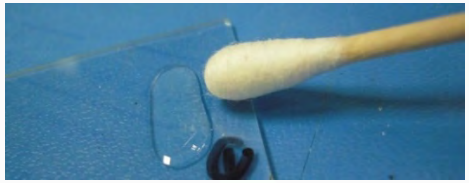
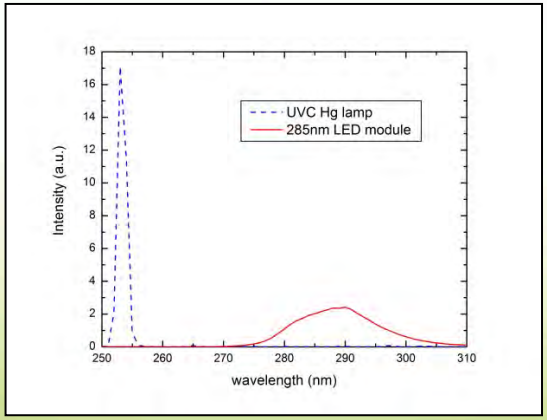
Evaluation Method

- **Selection criterion**
  - Adhesive and conformal coating samples that were difficult to cure with commercially available 365nm and 395nm light sources
  - Relevant to commercial opportunities



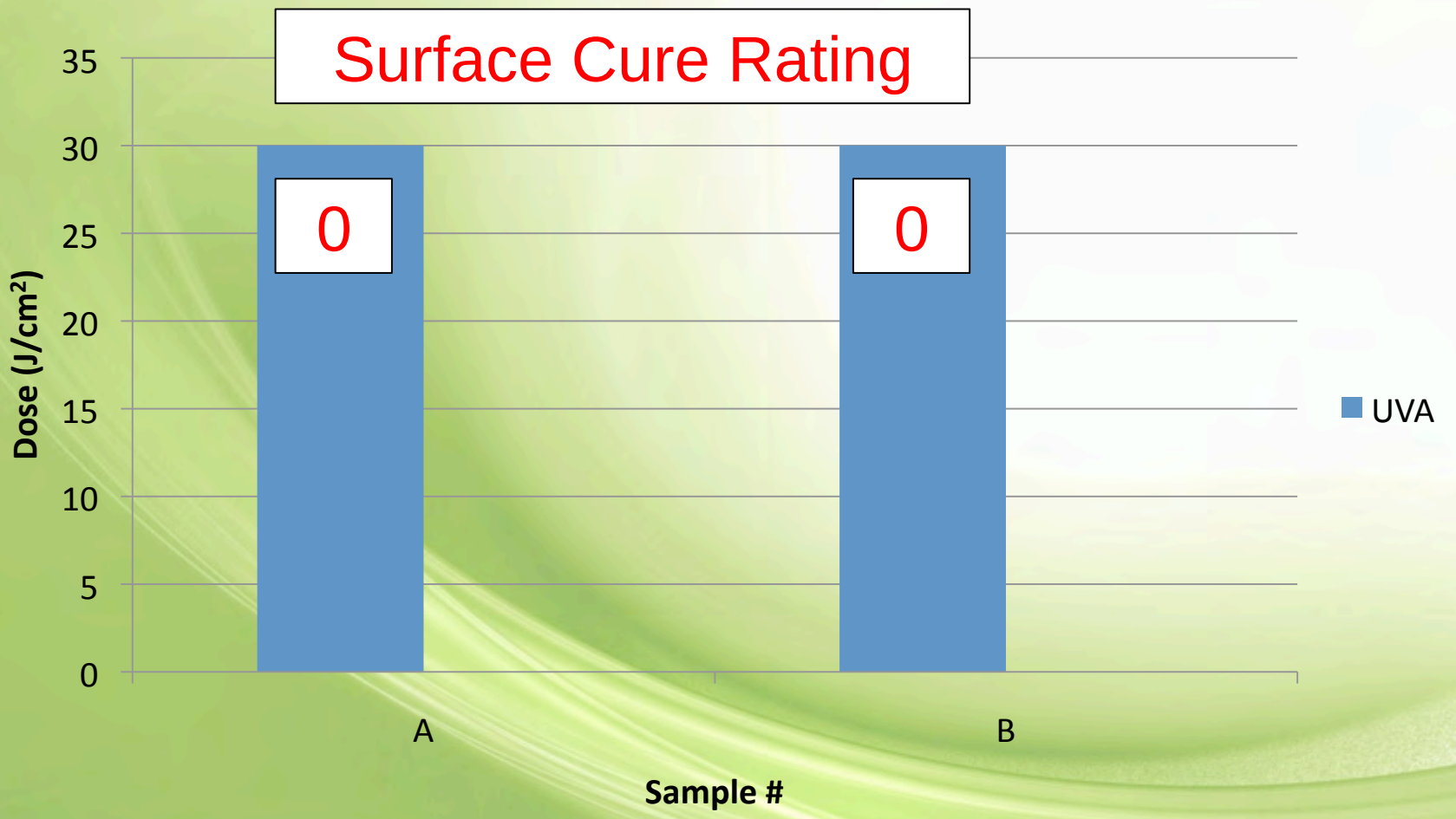
- **A scale between 0 and 5 has been adopted**
  - “5” is tack free (hard/strong surface; the best surface cure achievable)
  - “4” is tack free
  - “0” is wet surface
  - 0 < 1 < 2 < 3 < 4 < 5



- **Verification of results**
  - A UVC lamp was used to determine irradiance threshold needed to impact surface cure

Experimental Results - Adhesive

Two free radical adhesives – Samples A + B



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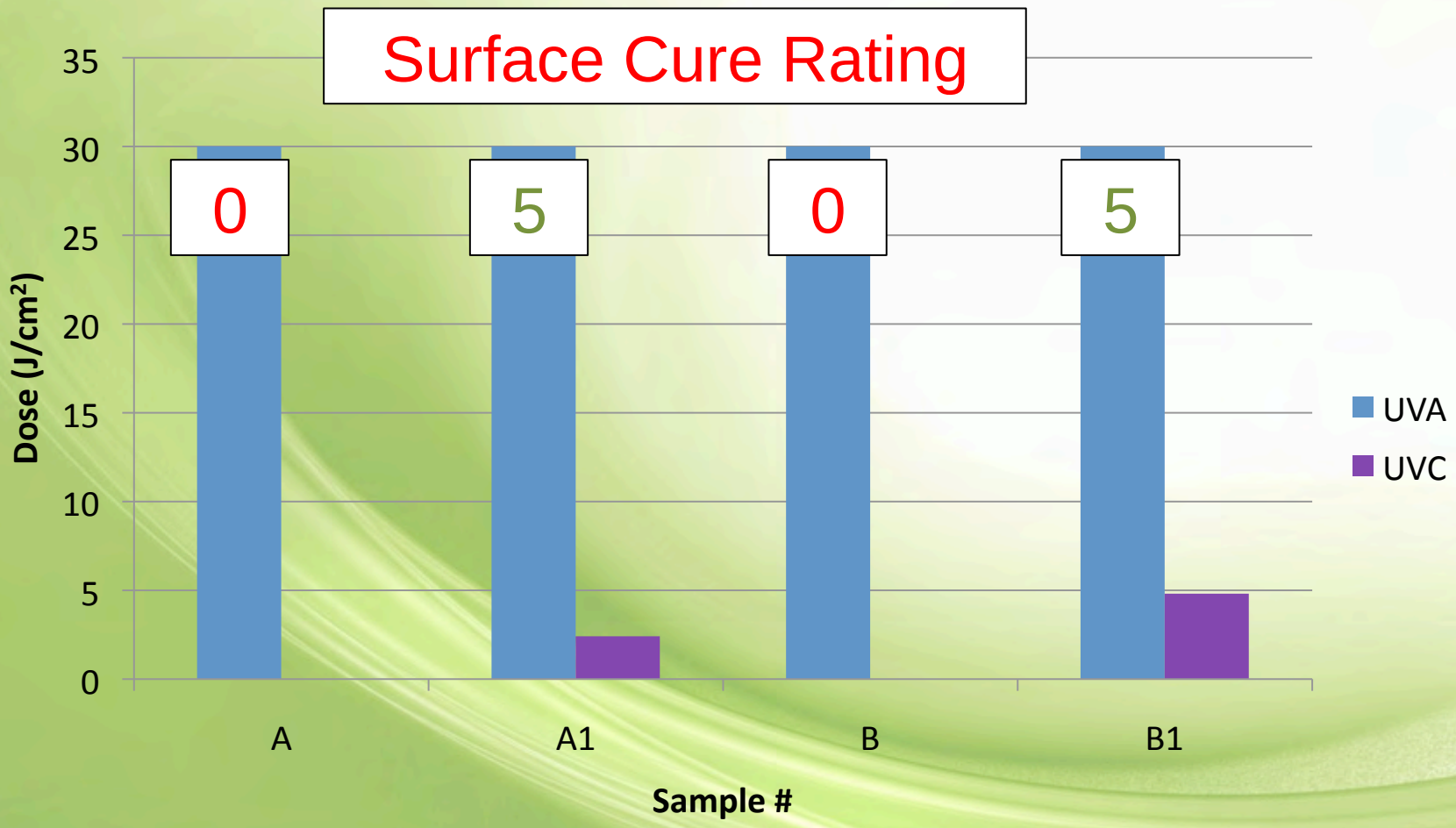
Experimental Results - Adhesive

- **Achieve tack-free surface with addition of UVC post-cure**



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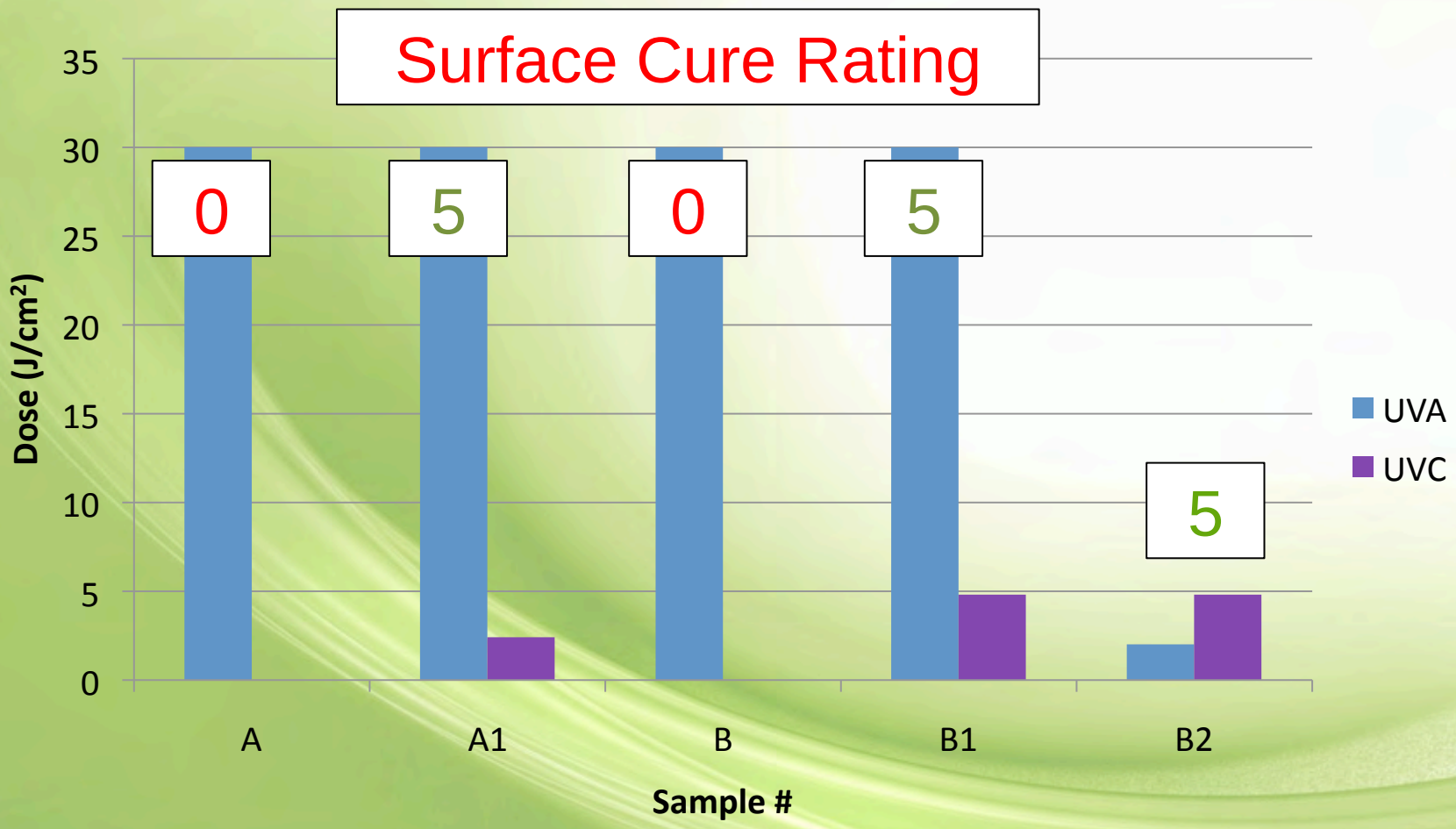
Experimental Results - Adhesive

- **Can you reduce UVA dose and still achieve same surface cure?**



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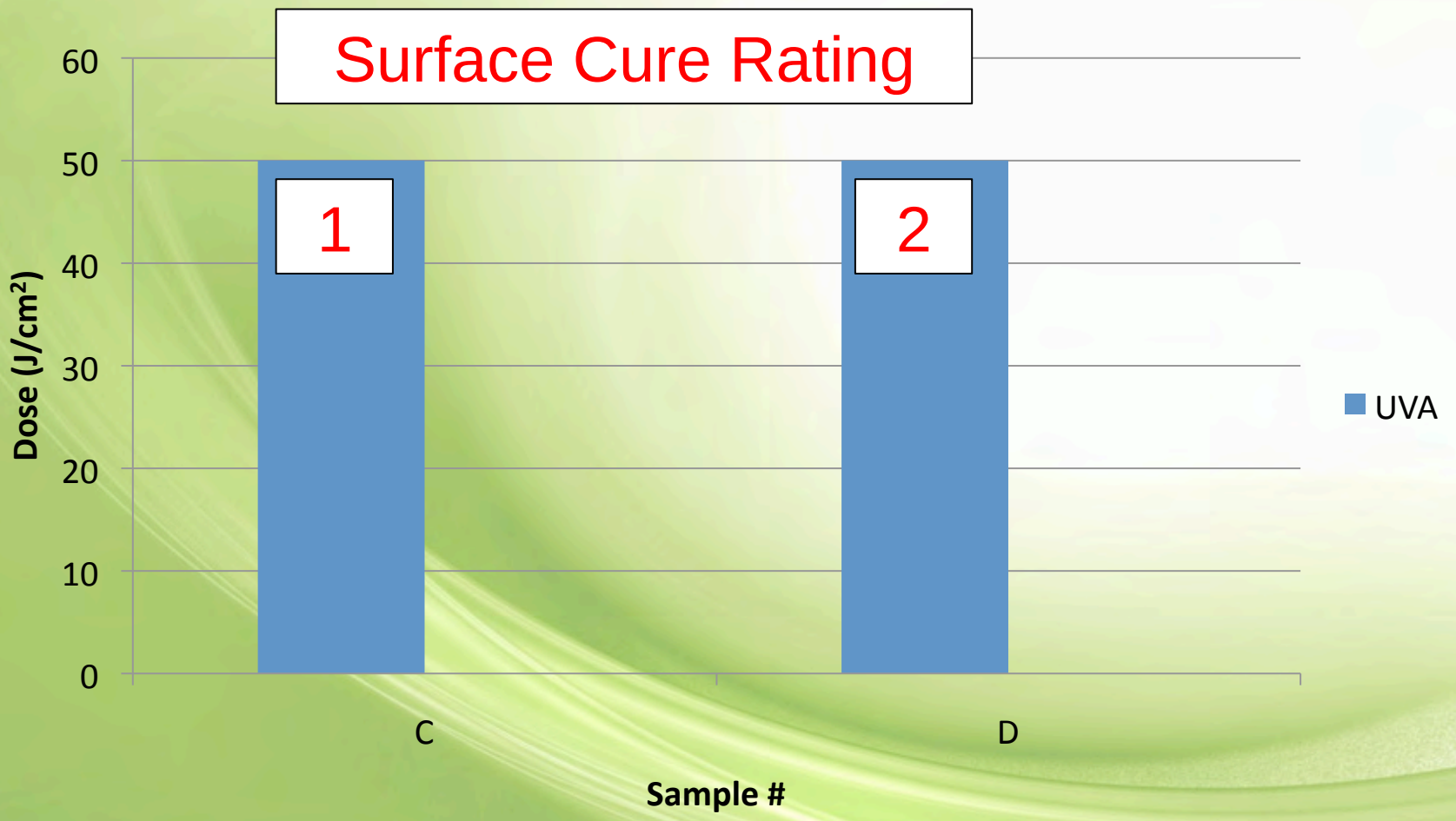
Initial Experimental Results

- Large UVA/UVV dose still left a wet surface
- Improved surface cure was achieved with addition of UVC LED exposure
- Addition of UVC allows for significant reduction of UVA/UVV dose
  - Able to achieve same surface finish

Experimental Results - Coatings

Two dual cure coatings – Samples C + D



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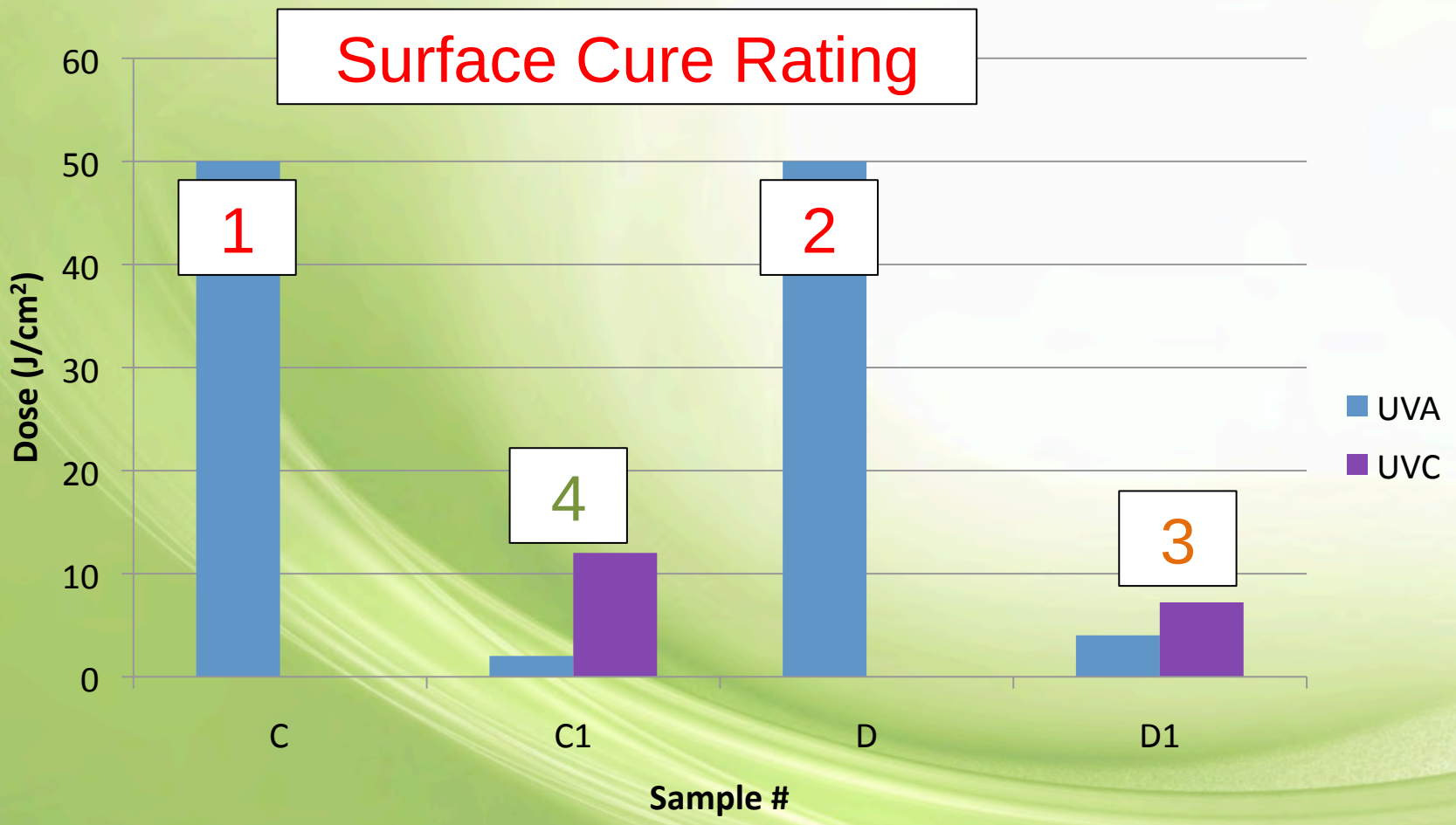
Experimental Results - Coatings

- Two dual cure coatings – Samples C + D



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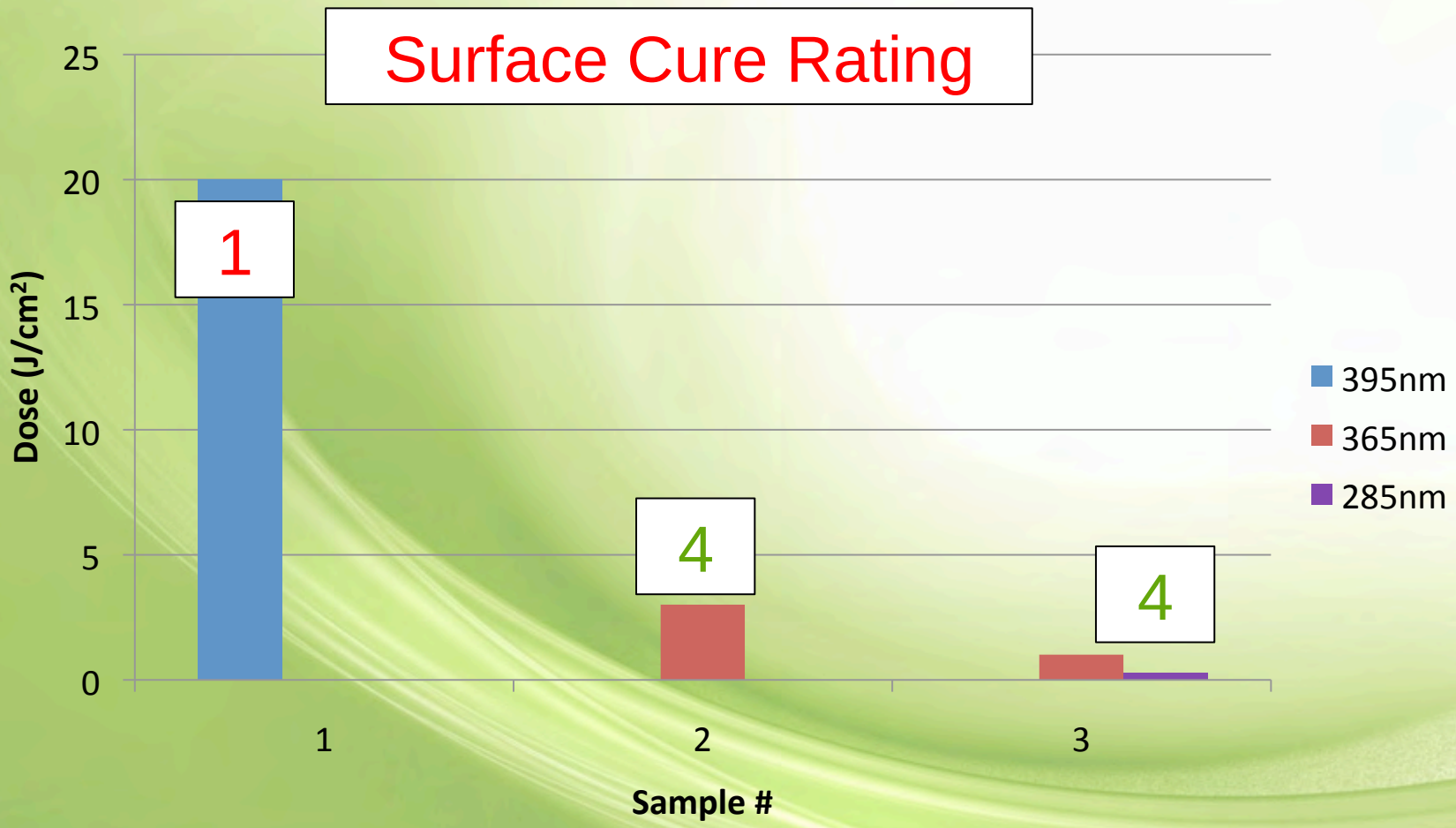
Initial Experimental Results – Dual Cure Coatings

- Large UVA/UVV dose still left a wet surface
  - Secondary cure mechanism provided hard surface after 6 – 12 hours
- Addition of UVC provides improved surface cure with significant reduction of UVA/UVV dose
  - Not always able to achieve acceptable surface finish

Experimental Results – Multiple Wavelengths

- Lower wavelength can require lower dose



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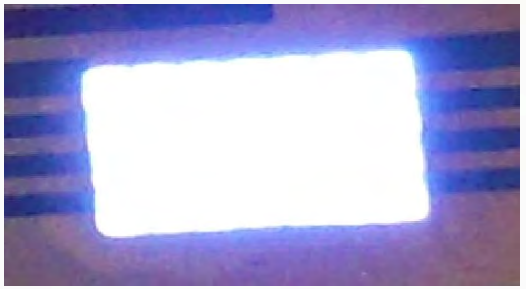
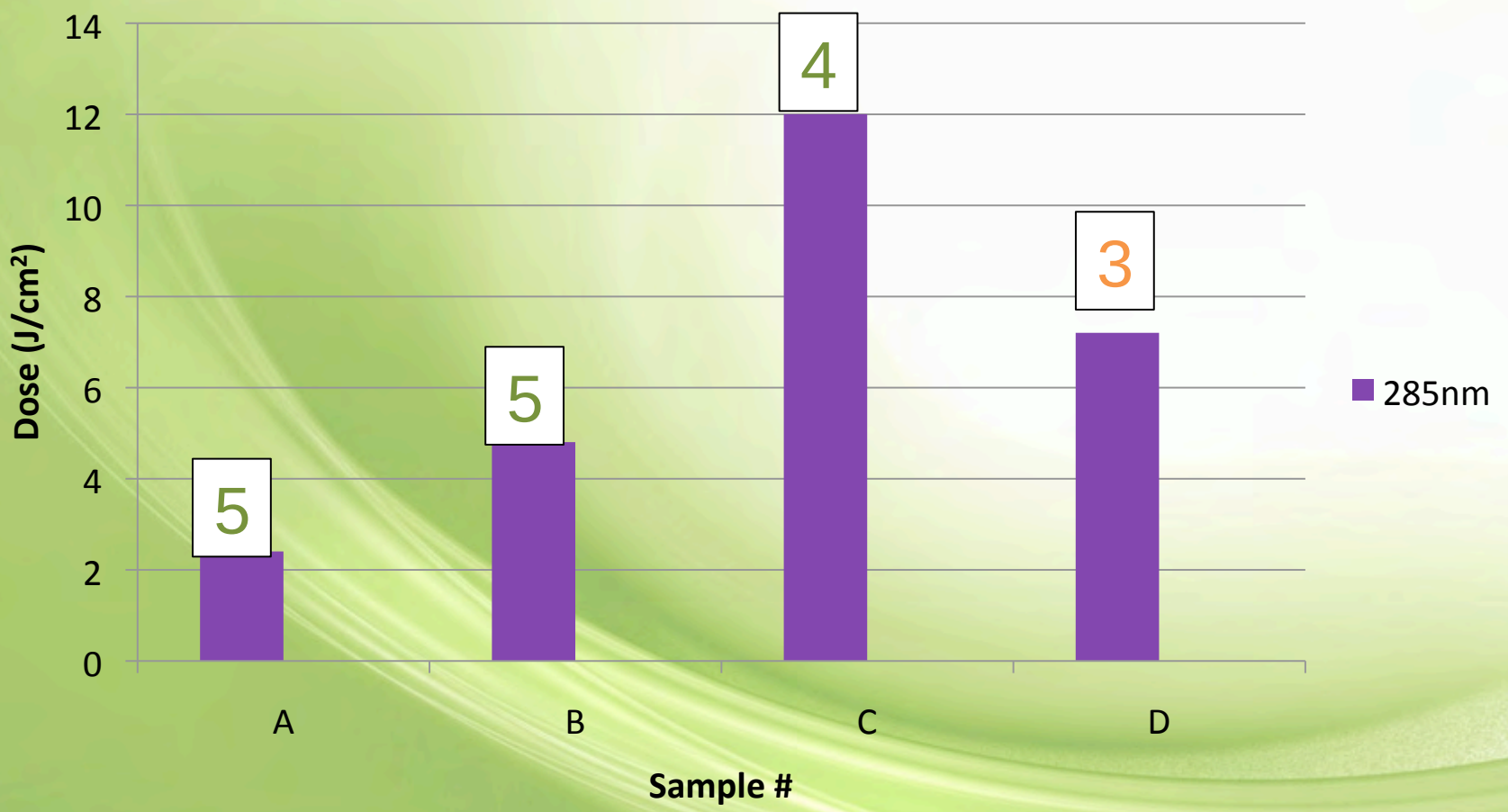
Ongoing Testing

- Efficiency of UVC LEDs continues to increase
- Lower wavelengths available in higher power
  - Over 2X the irradiance of previous test systems
- More flexibility for system design improvements



Wavelength Effect – Previous Results



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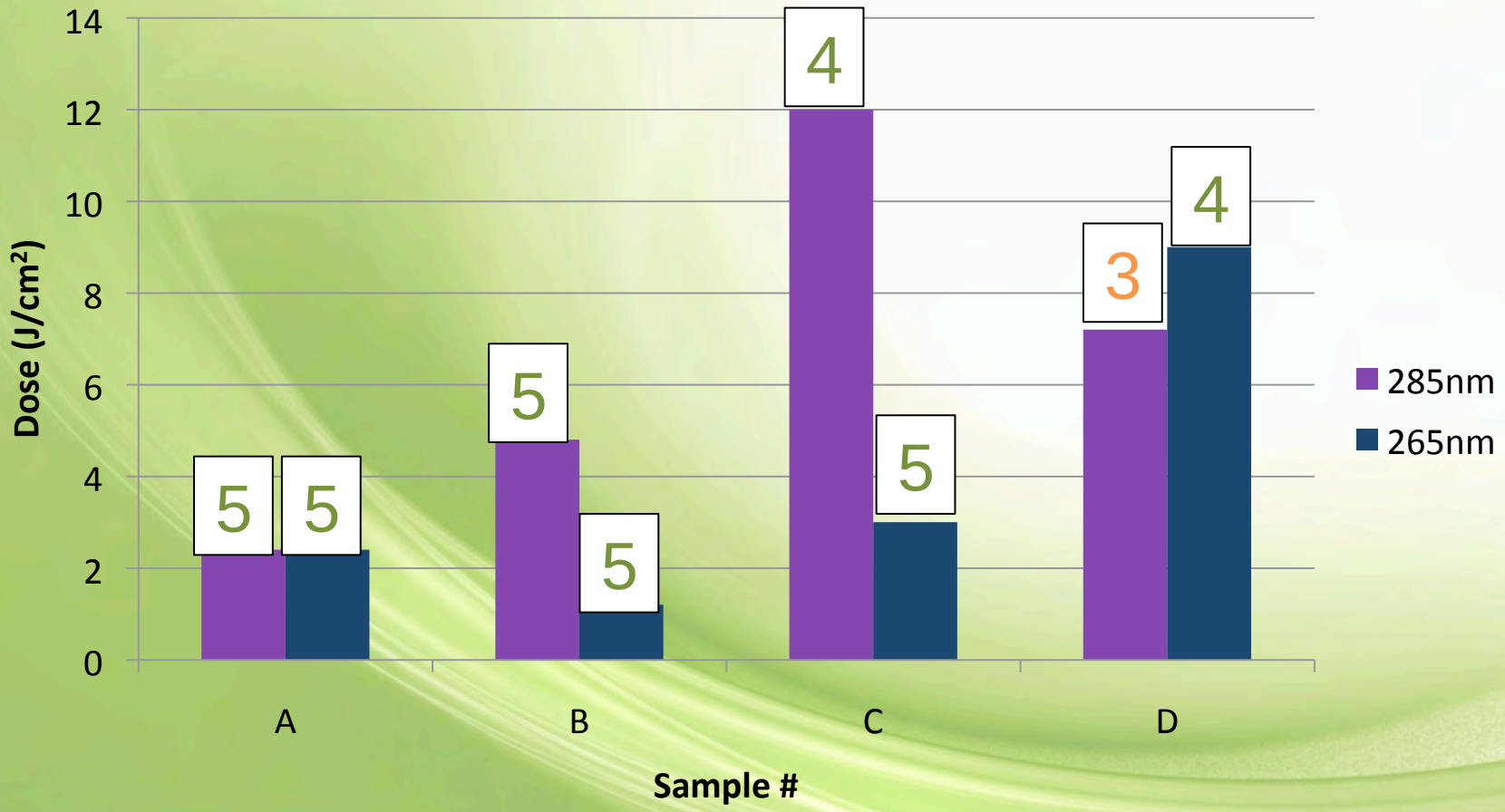
Wavelength Effect – Lower Wavelength

- **May be able to reduce dose and/or improve surface finish with lower wavelength, higher irradiance**



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The Path Forward …

- Ongoing advances in UVC LED technology should bring benefit to the UV curing industry
  - Improved surface cure
  - Minimize need for complex formulation modification
- Rapid advancement in core technology
  - Improved power output (>10x in last few years)
  - Increase current densities & lifetime
  - Decreasing LED die costs as yields improve
- Commercial success will depend on advanced system design optimized for the application
  - Balance cost vs. performance
  - Wavelength selection
- Further cure trials are necessary

Thank You

Questions?

Come visit us at Booth # 713

Contact: Mike Kay

Director of Product Management, OmniCure

Excelitas Technologies

Mike.Kay@excelitas.com

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