Cleaning of Silicone and Hydrocarbon Contact Residue Using Atmospheric Plasma

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Outline

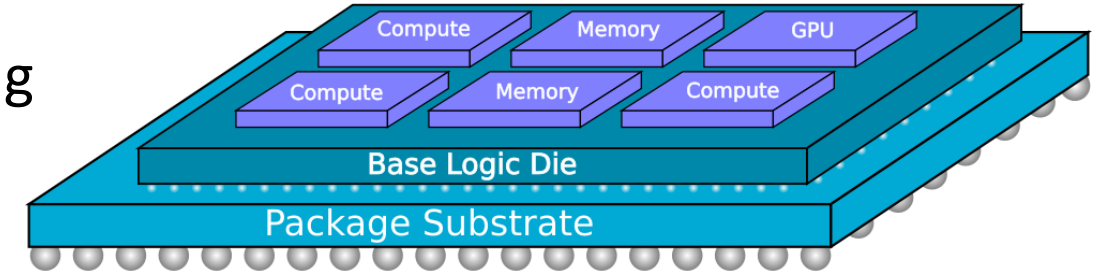
- Introduction
- Experimental Setup
- Results and Discussion
- Conclusion

Introduction

- Surface cleanliness is important for many advanced packaging process steps especially for direct bonding interconnect and hybrid bonding.
- Adhesive films are ubiquitous in chip packaging
  - Dicing tapes
  - Gel-type transport trays
- Contact with adhesive film degrades the surface properties of the device.
- Small amount of residue remains on chip surface after release, which decreases surface energy and reduces bonding strength.
- We use water contact angle (WCA) and Fourier transform infrared (FTIR) metrology to analyze contact residue.
- We utilize an atmospheric plasma system for cleaning the residue to increase adhesion in a direct bonding application.

The rise of heterogeneous 3D-IC:

- New technologies such as 5G, artificial intelligence, virtual reality, and autonomous vehicles are pushing microelectronics towards faster performance, smaller packaging, lower cost.
- Heterogeneous 3D-IC is an emerging interconnection approach for addressing current and future high-performance demands.
- Included in many advanced packaging roadmaps around the world.



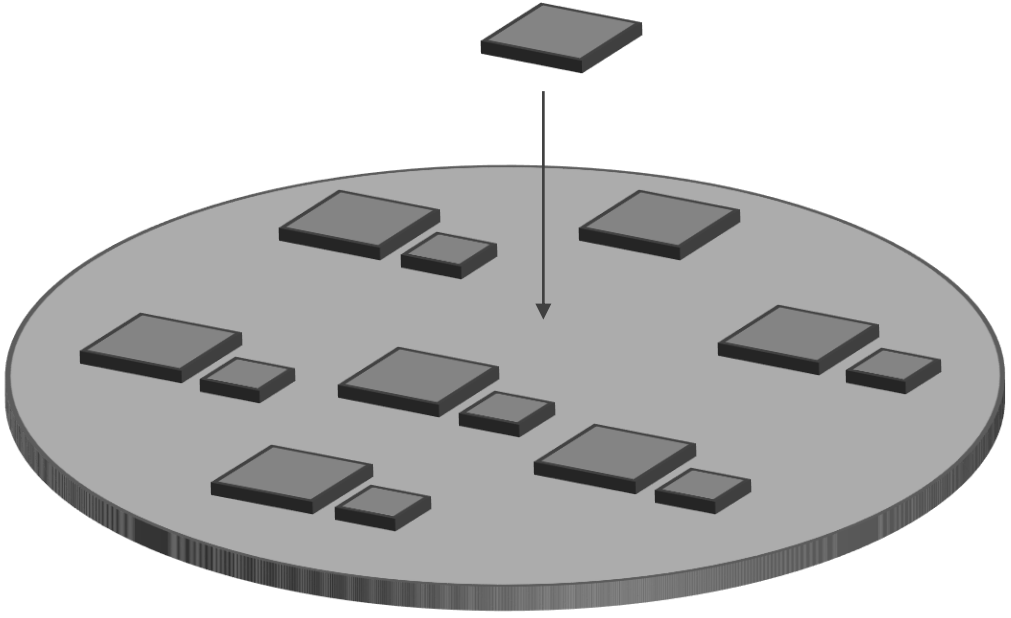
Die-to-Wafer hybrid bonding

Benefits

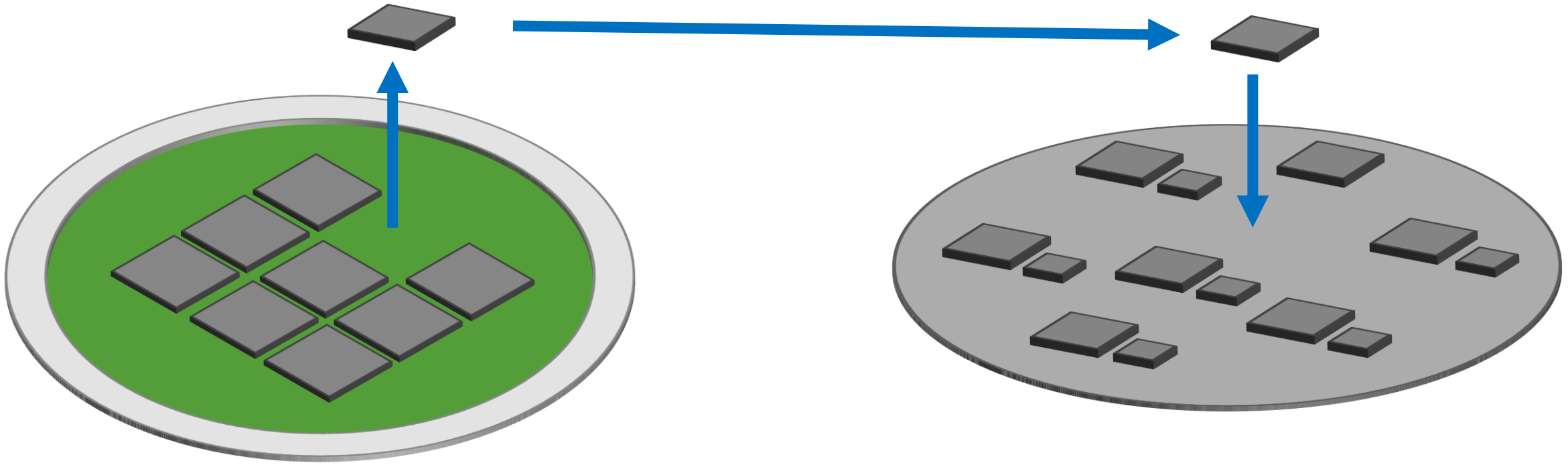
- Increase Yield: use only known good die
- Most flexible: Die can be different size, thickness, material, supplier etc.
- Room temperature bond, batch anneal

Challenges

- Slower throughput compared to W2W
- Higher risk of contamination from equipment and handling.



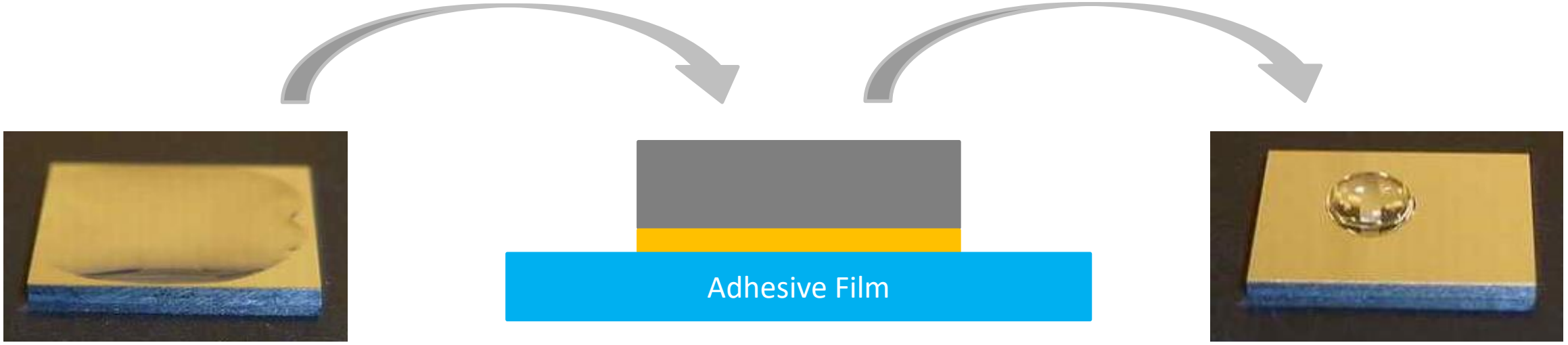
Simple chip-handling flow for D2W direct hybrid bonding



- Singulated chips face side down on dicing film
- Can also be from gel tray (vacuum release)

- Direct bond chip to wafer for heterogeneous integration

Contamination from adhesive film

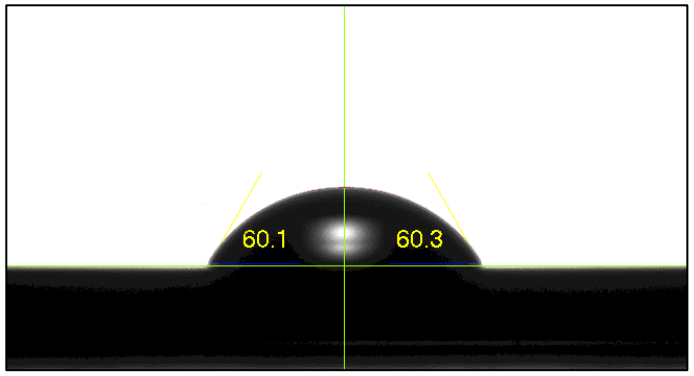


Hydrophilic surface
(Clean)

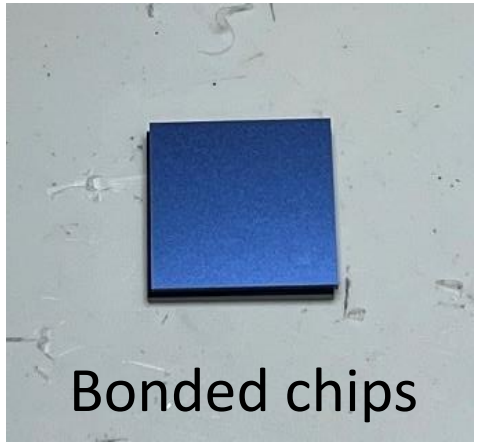
Hydrophobic surface
(Contaminated)

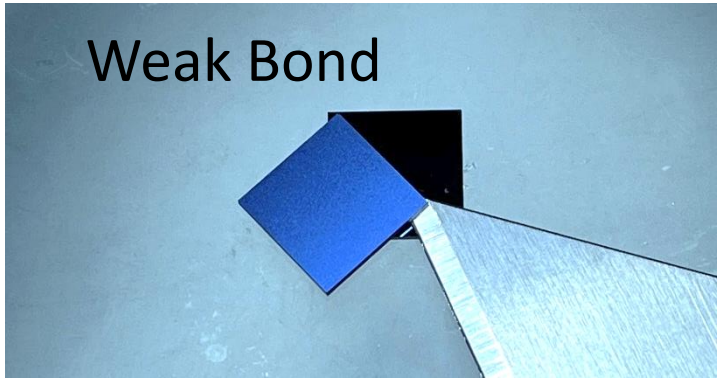
- Surface becomes hydrophobic after contact with adhesive film
- Although no visible residue, there is contamination at molecular level
- Water contact angle is sensitive to molecular surface changes

Contamination reduces bond strength

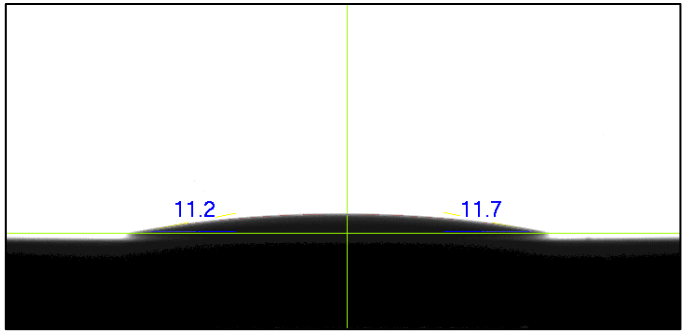


Hydrophobic surface
(Contaminated from adhesive film)

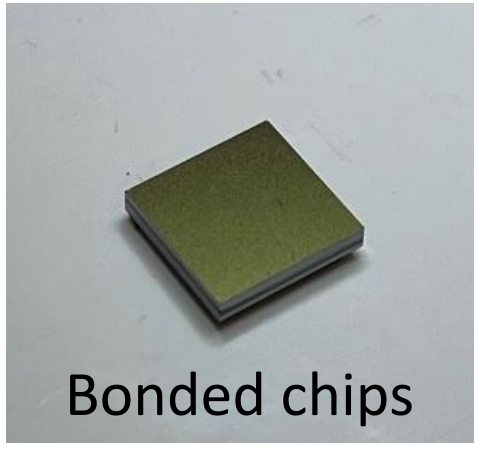


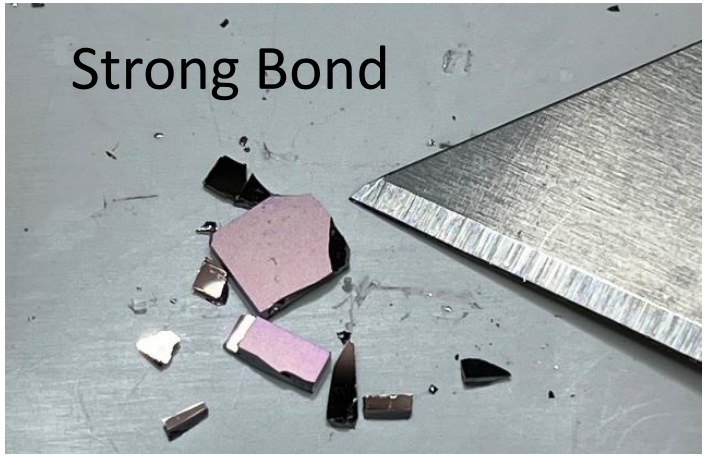


Easily separates upon razor insertion



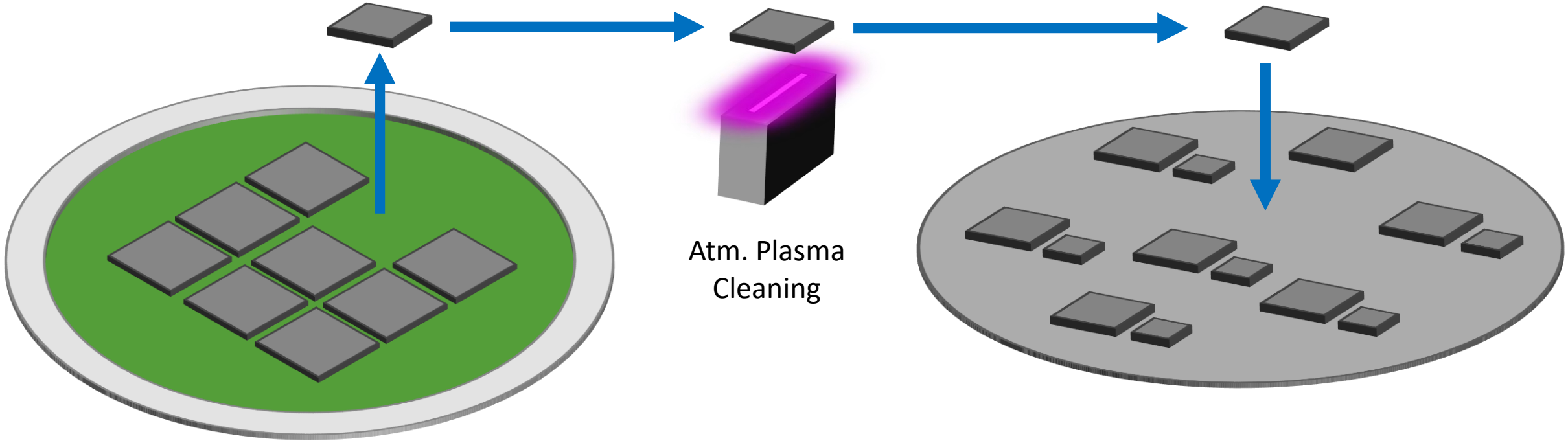
Hydrophilic surface
(Plasma Cleaned)





Bulk fracture upon razor insertion

Simple chip-handling flow with plasma clean

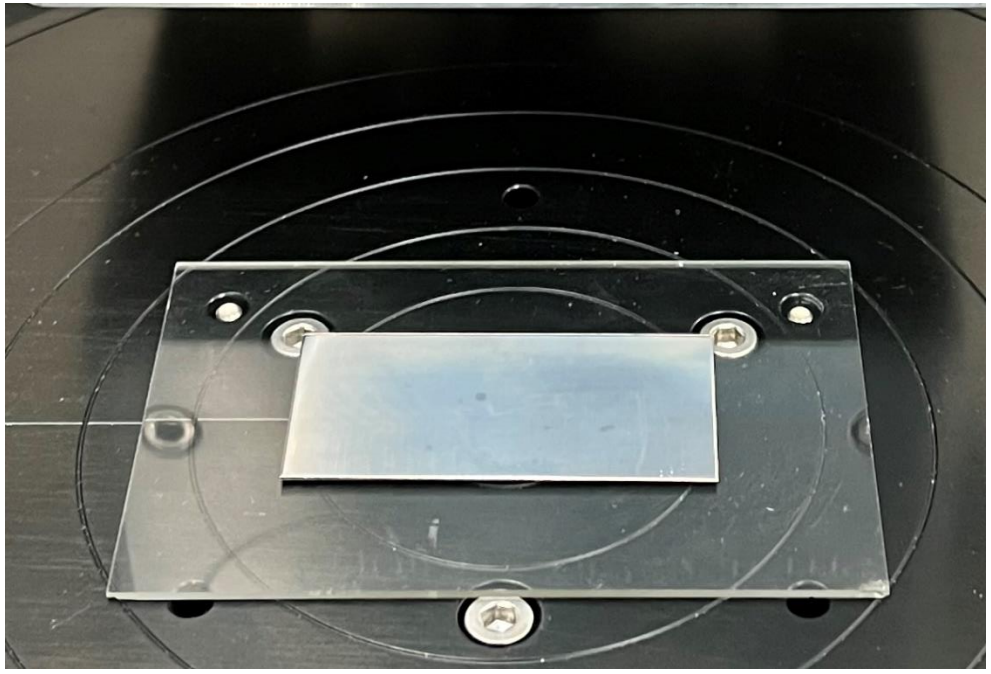


- Singulated chips face side down on dicing film
- Can also be from gel tray (vacuum release)

- Direct bond chip to wafer for heterogeneous integration

Experimental Setup

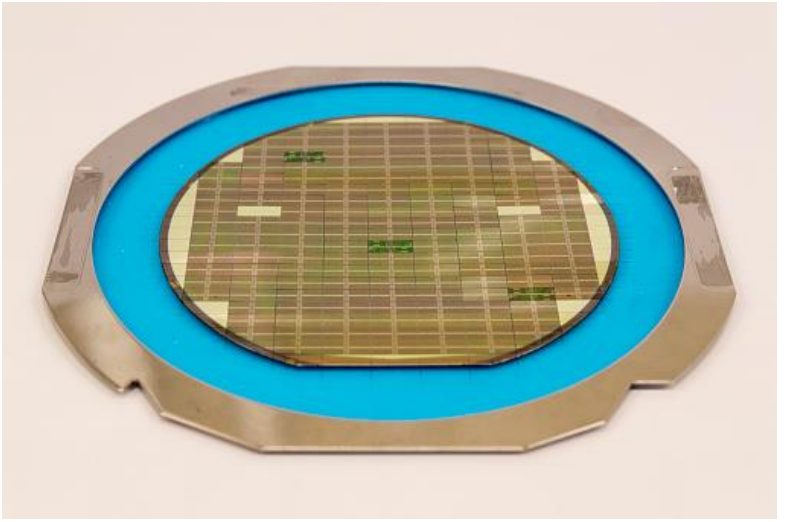
Test coupons used for contacting adhesive film



- Ferrotype Plate (FTP)
- Chrome coated steel plates
- 25mm x 50mm coupons
- Inexpensive, works well with FTIR

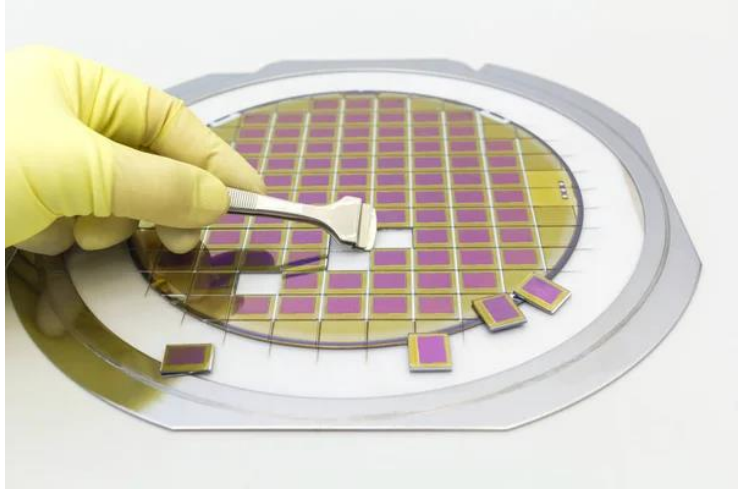
Four Adhesive Films Tested

Gel tack level 4
Gel tack level 8



Blue Dicing Tape

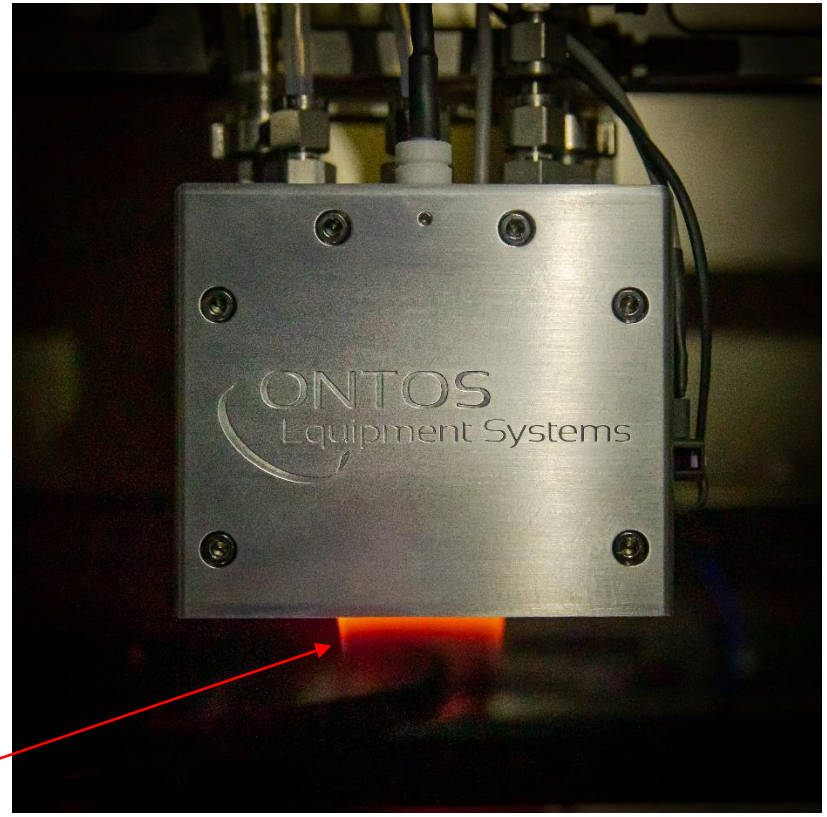
UV Release
Dicing Tape



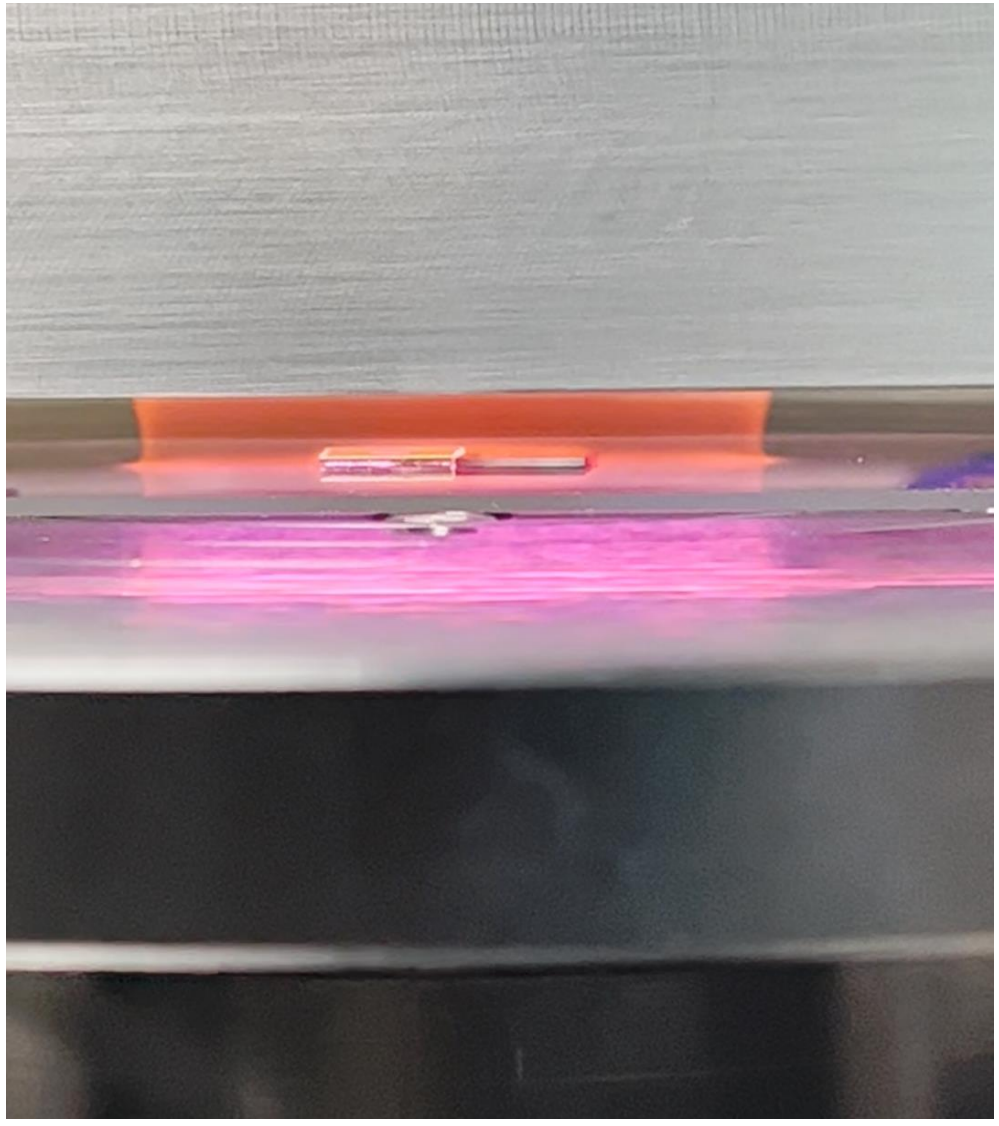
Atmospheric Plasma

- We have developed a compact Plasma Treatment System designed to operate at atmospheric pressure to address the specific needs of D2W hybrid bonding.

- Creates radical H*, N*, O* chemical species used to clean and activate surfaces prior to bonding.
- Designed to be ultra clean and safe for sensitive electronic devices.

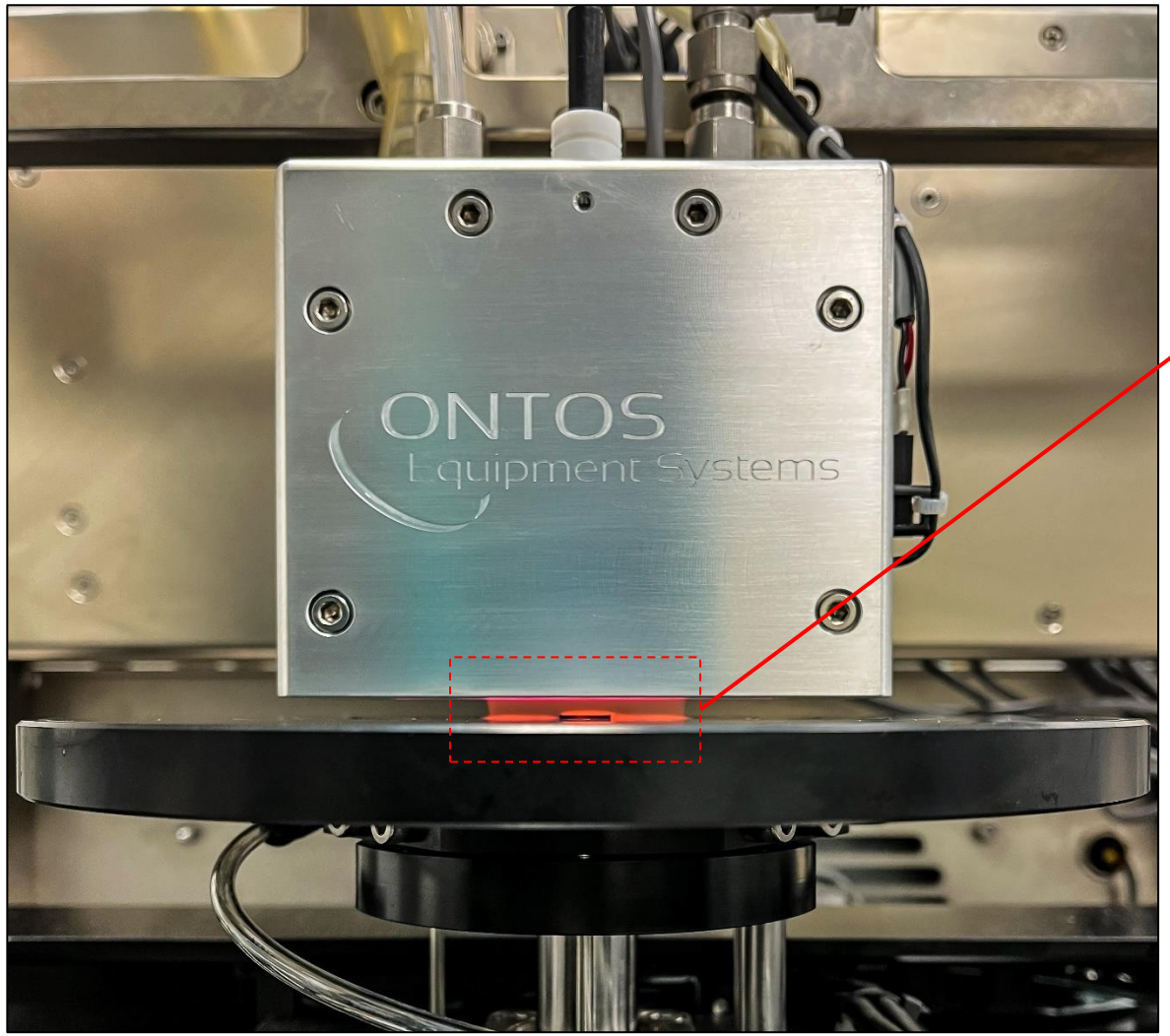


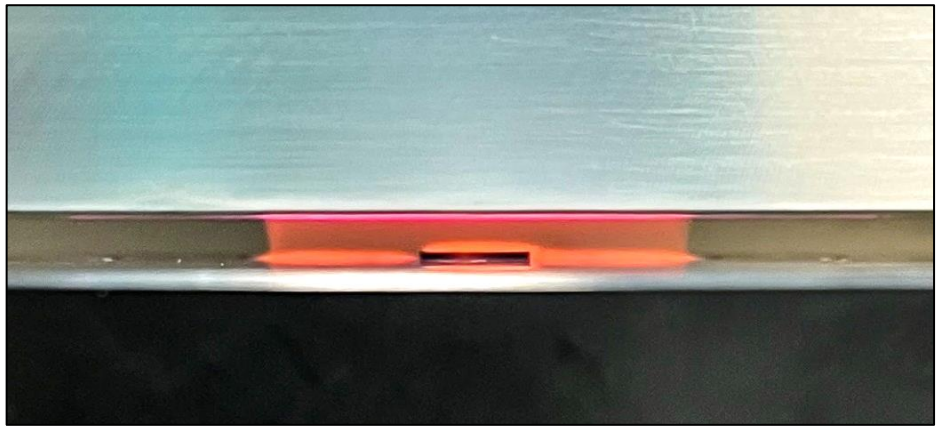
Video of Atmospheric Plasma Process



Fun Atmospheric Plasma Demonstration
Using a stencil (mask) to create a secret message
Video

Atmospheric Plasma Treatment of FTPs





Plasma process recipes used on FTPs:

1: $He+O_2$ plasma

2: $He+H_2$ plasma

3: $He+O_2+H_2$ plasma

Metrology

(collaboration with Brighton Science)

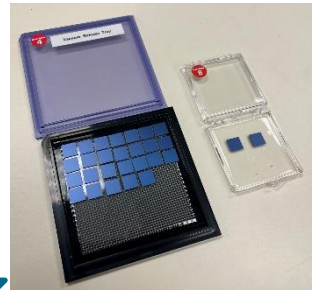
Water Contact Angle Goniometer
(Top-down image acquisition)

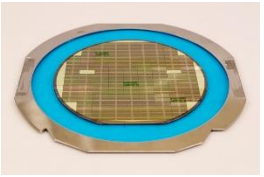
Fourier Transform Infrared Spectrometer
(FTIR)

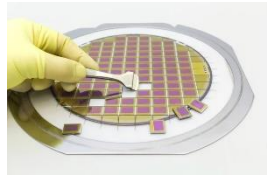
Process flow

Prepare clean FTP samples, collecting baseline WCA data

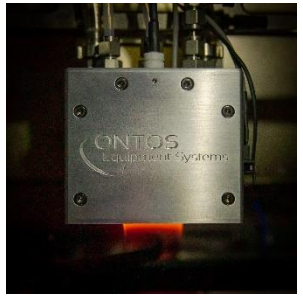
Touch each of the four adhesive films to the FTPs, collect WCA and FTIR data.







1: He+O2 Plasma
2: He+H2 Plasma
3: He+O2+H2 Plasma



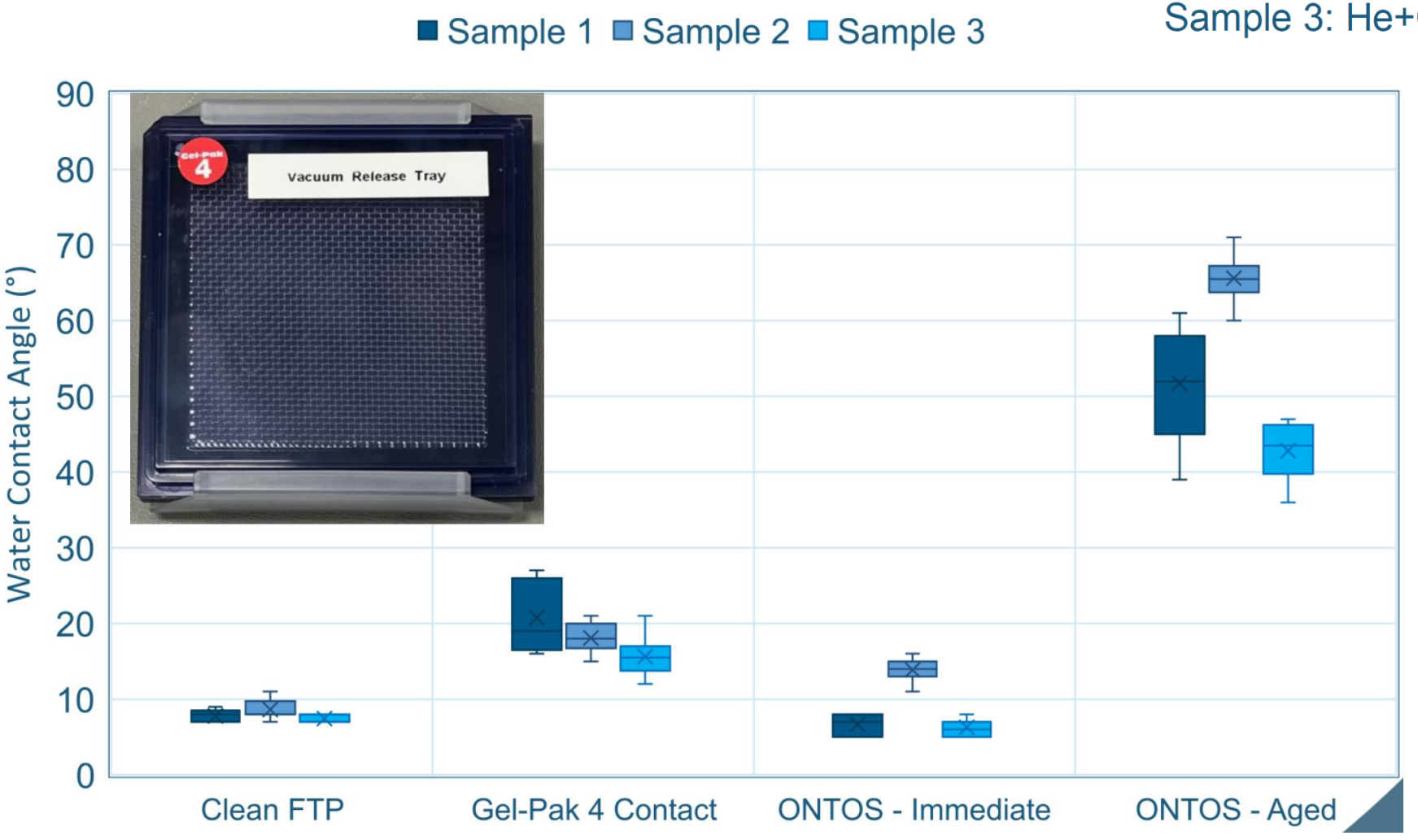
Expose FTPs to three types of ONTOS plasma recipes, collect immediate WCA data

Collect WCA and FTIR data of aged FTP samples

Results and Discussion

Gel-Pak 4: Water Contact Angle

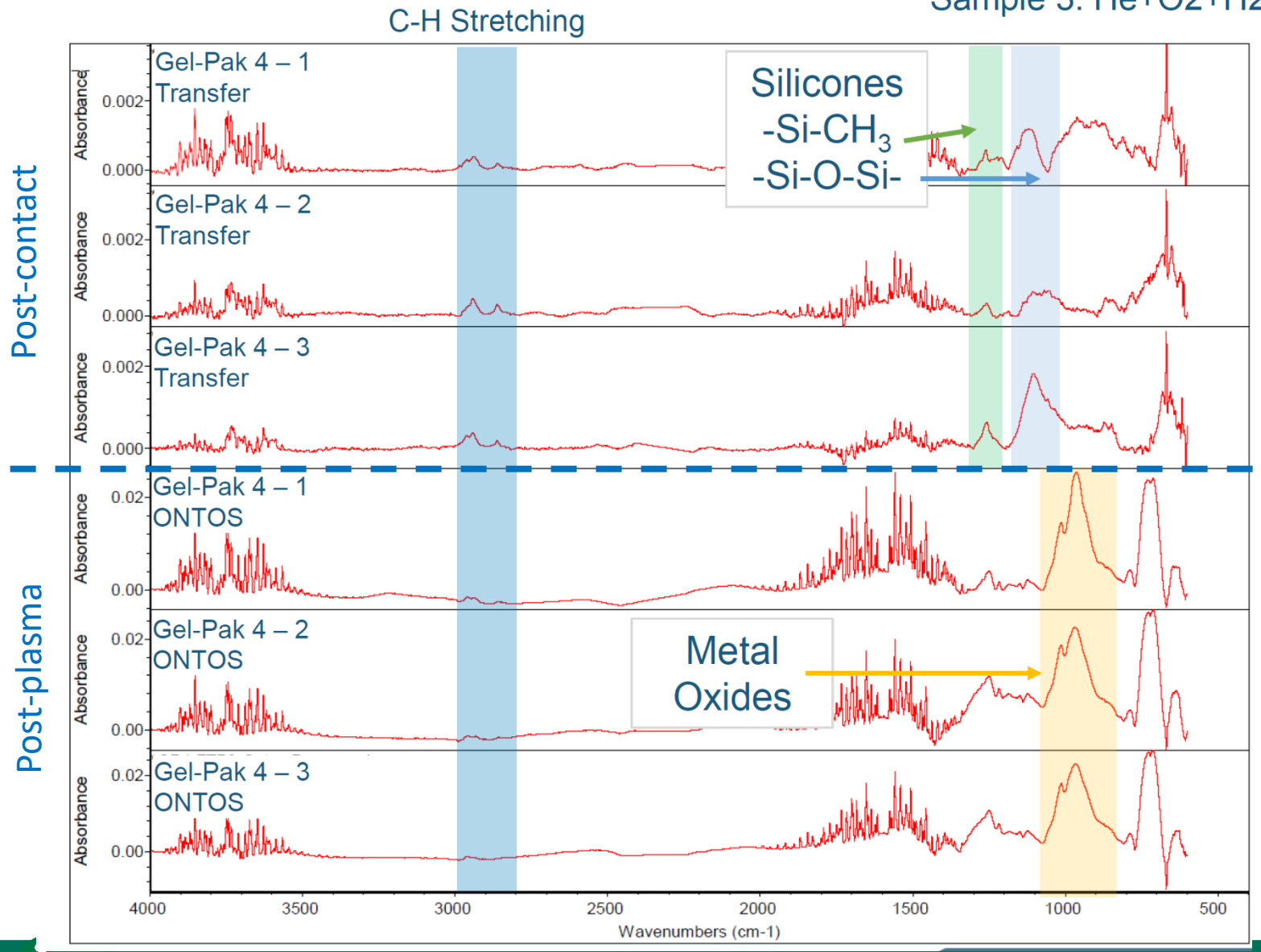
Sample 1: He+O2 Plasma
Sample 2: He+H2 Plasma
Sample 3: He+O2+H2 Plasma



- Contact with Gel 4 increased contact angle by 5-10°
- ONTOS treatment reduced contact angle by 5-15 °
- Aging of samples showed increase in contact angle by 40-50 °

Gel-Pak 4: FTIR

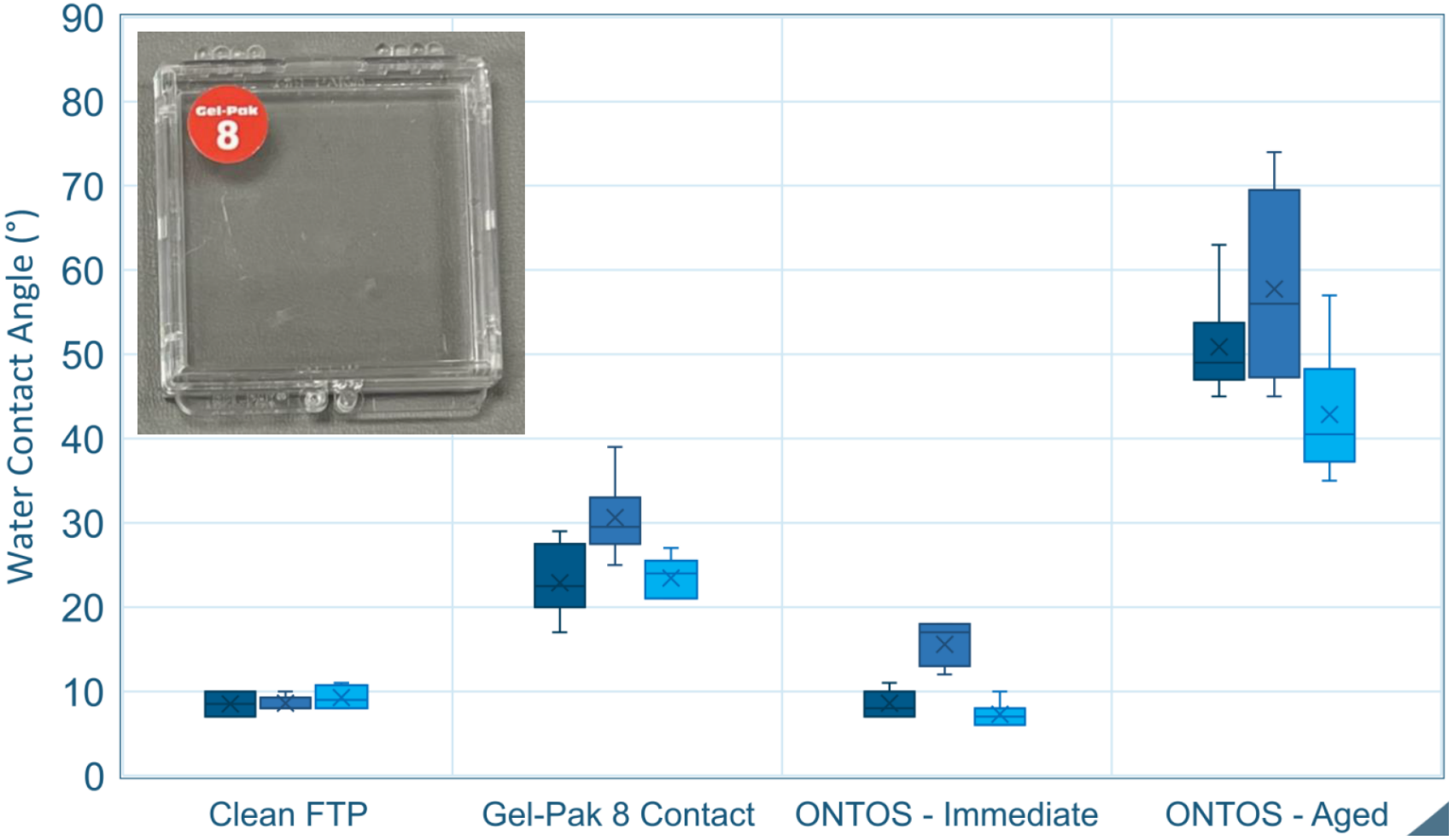
Sample 1: He+O2 Plasma
Sample 2: He+H2 Plasma
Sample 3: He+O2+H2 Plasma



- Hydrocarbons and silicones are present on coupons after material contact
- Hydrocarbon and silicone peaks significantly reduced or eliminated post-treatment
- Metal oxides present after aging in oxygen enviroment

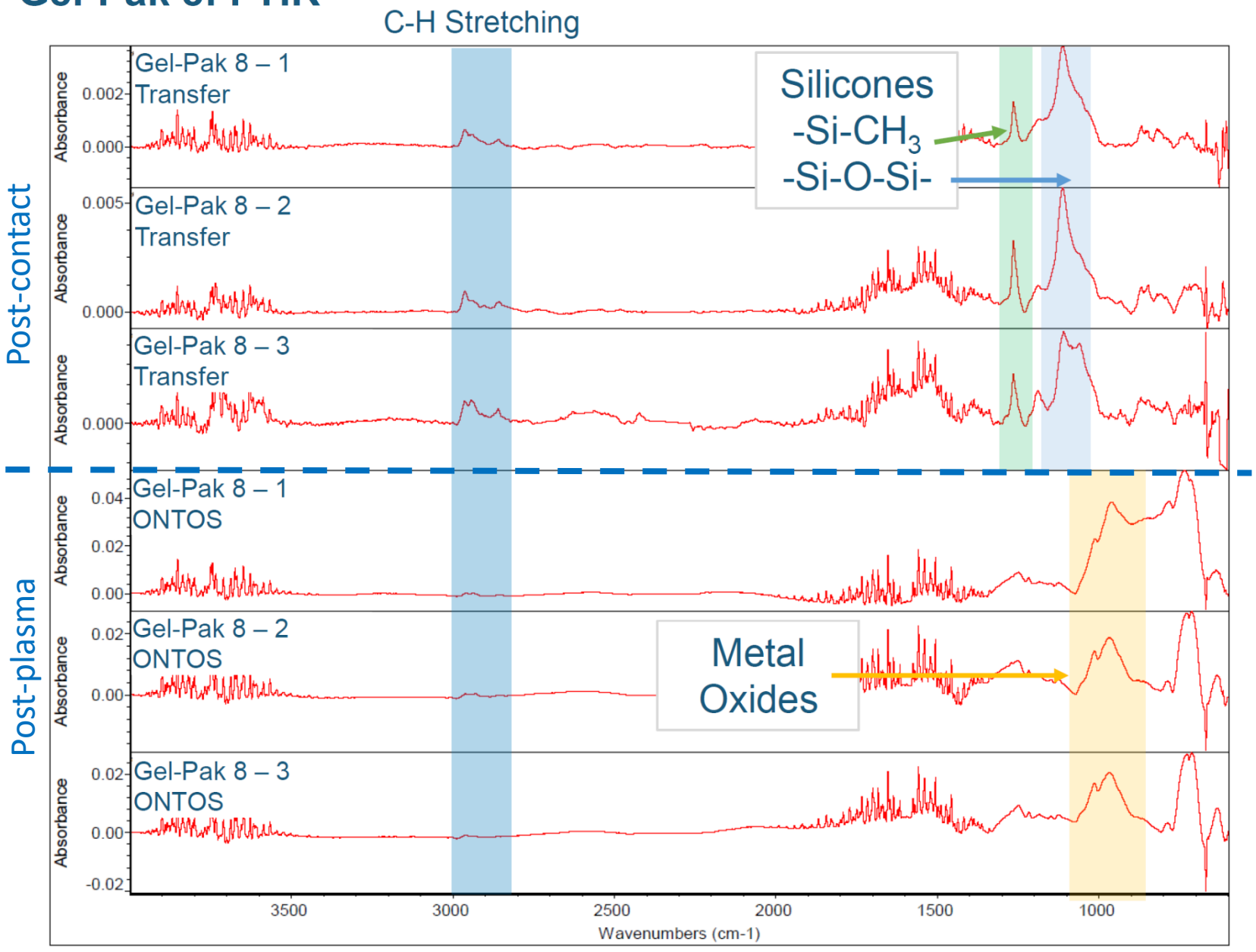
Gel-Pak 8: Water Contact Angle

Sample 1: He+O2 Plasma
Sample 2: He+H2 Plasma
Sample 3: He+O2+H2 Plasma



- Contact with Gel 8 increased contact angle by 10-20°
- ONTOS treatment reduced contact angle by 10-15°
- Aging of samples showed increase in contact angle by 30-40°

Gel-Pak 8: FTIR

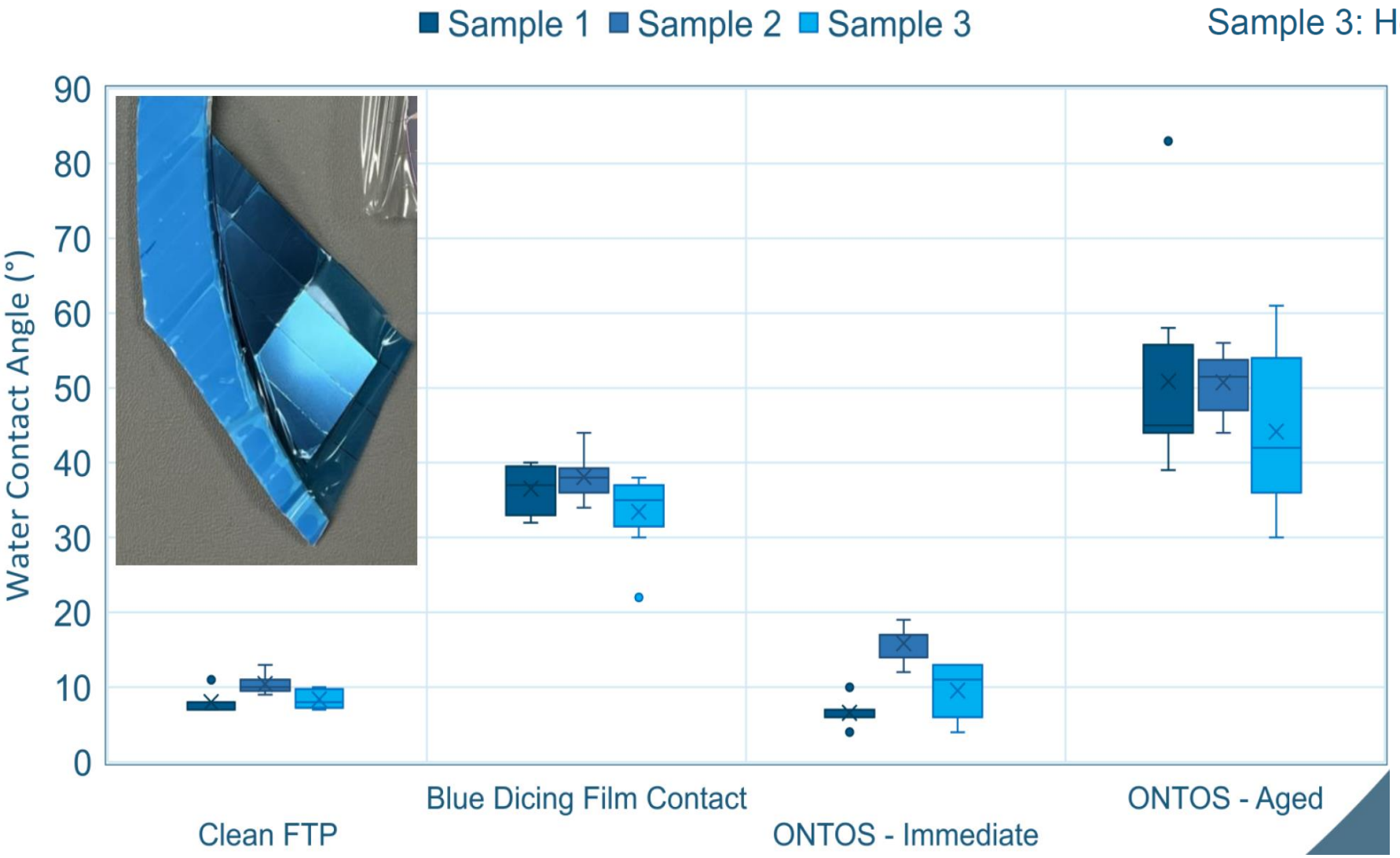


Sample 1: He+O2 Plasma
Sample 2: He+H2 Plasma
Sample 3: He+O2+H2 Plasma

- Hydrocarbons and silicones are present on coupons after material contact
- Hydrocarbon and silicone peaks significantly reduced or eliminated post-treatment
- Metal oxides present after aging in oxygen environment

Tape A: Blue Dicing Tape: Water Contact Angle

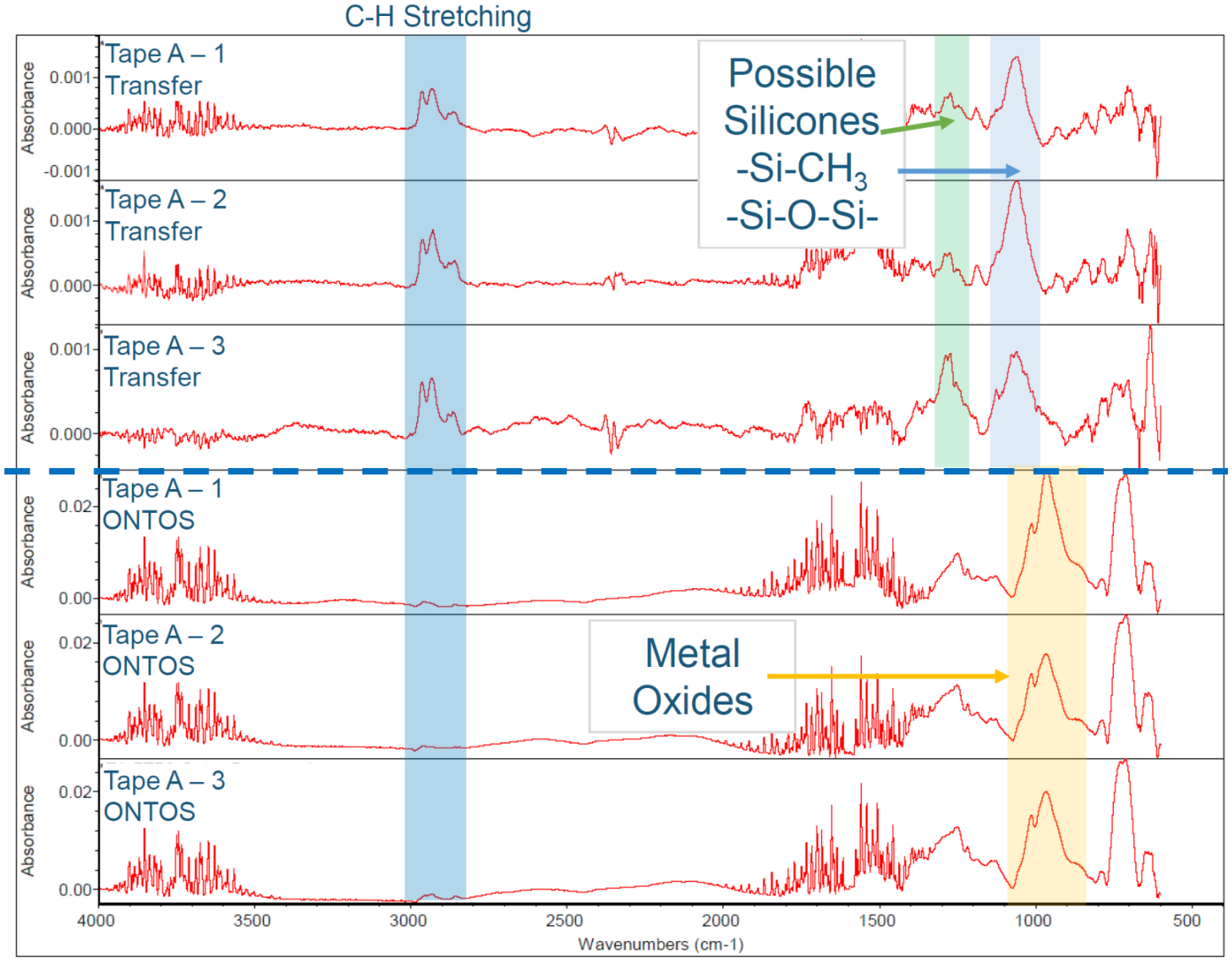
Sample 1: He+O2 Plasma
Sample 2: He+H2 Plasma
Sample 3: He+O2+H2 Plasma



- Contact with Gel 4 increased contact angle by 20-30°
- ONTOS treatment reduced contact angle by 20-30°
- Aging of samples showed increase in contact angle by 20-40°

Tape A: Blue Dicing Tape:

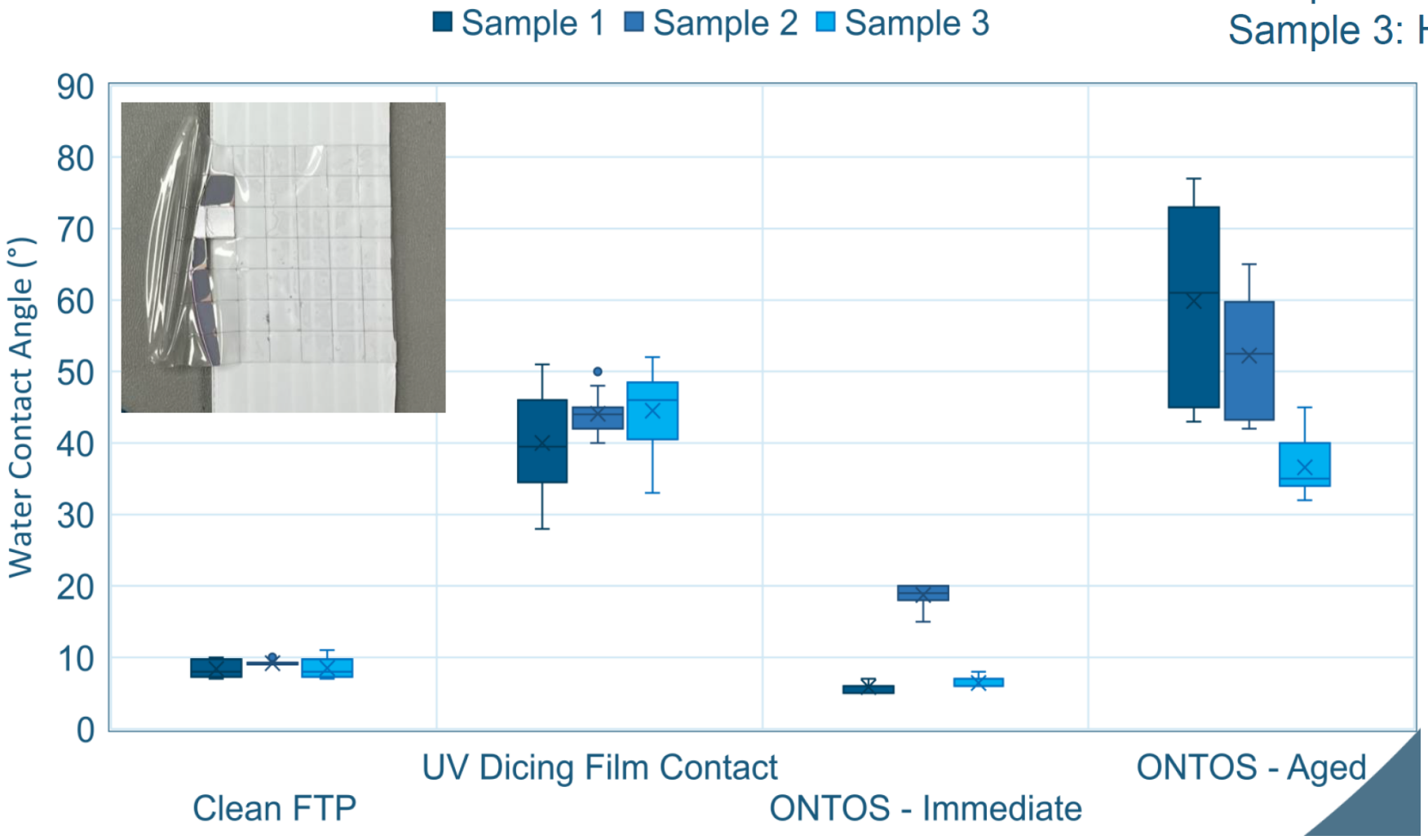
Sample 1: He+O2 Plasma
Sample 2: He+H2 Plasma
Sample 3: He+O2+H2 Plasma



- Hydrocarbons and possibly silicones are present on coupons after material contact
- Hydrocarbon and potential silicone peaks significantly reduced or eliminated post-treatment
- Metal oxides present after aging in oxygen environment

Tape B: UV Dicing Film: Water Contact Angle

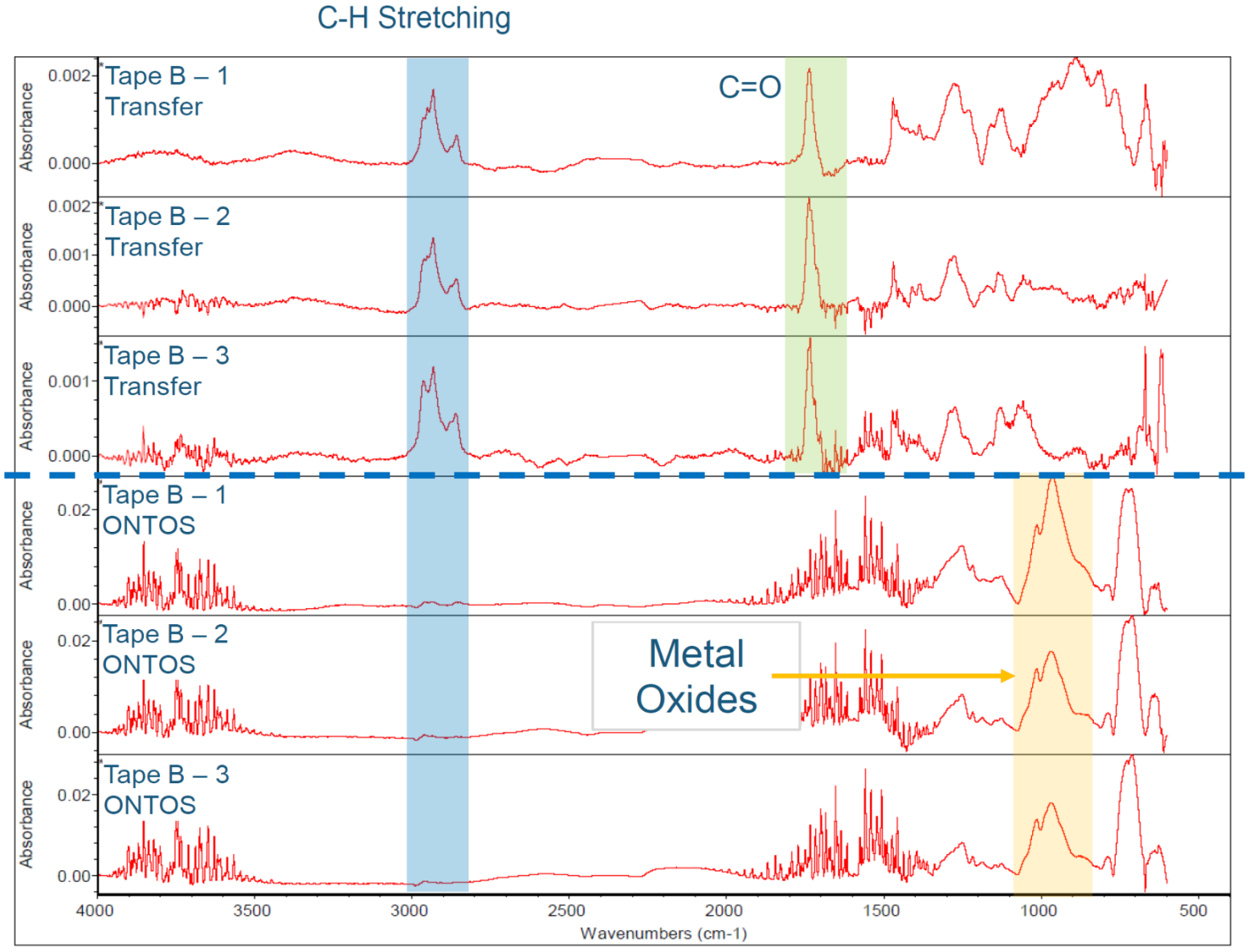
Sample 1: He+O2 Plasma
Sample 2: He+H2 Plasma
Sample 3: He+O2+H2 Plasma



- Contact with Gel 4 increased contact angle by 25-40°
- ONTOS treatment reduced contact angle by 20-35 °
- Aging of samples showed increase in contact angle by 25-60°

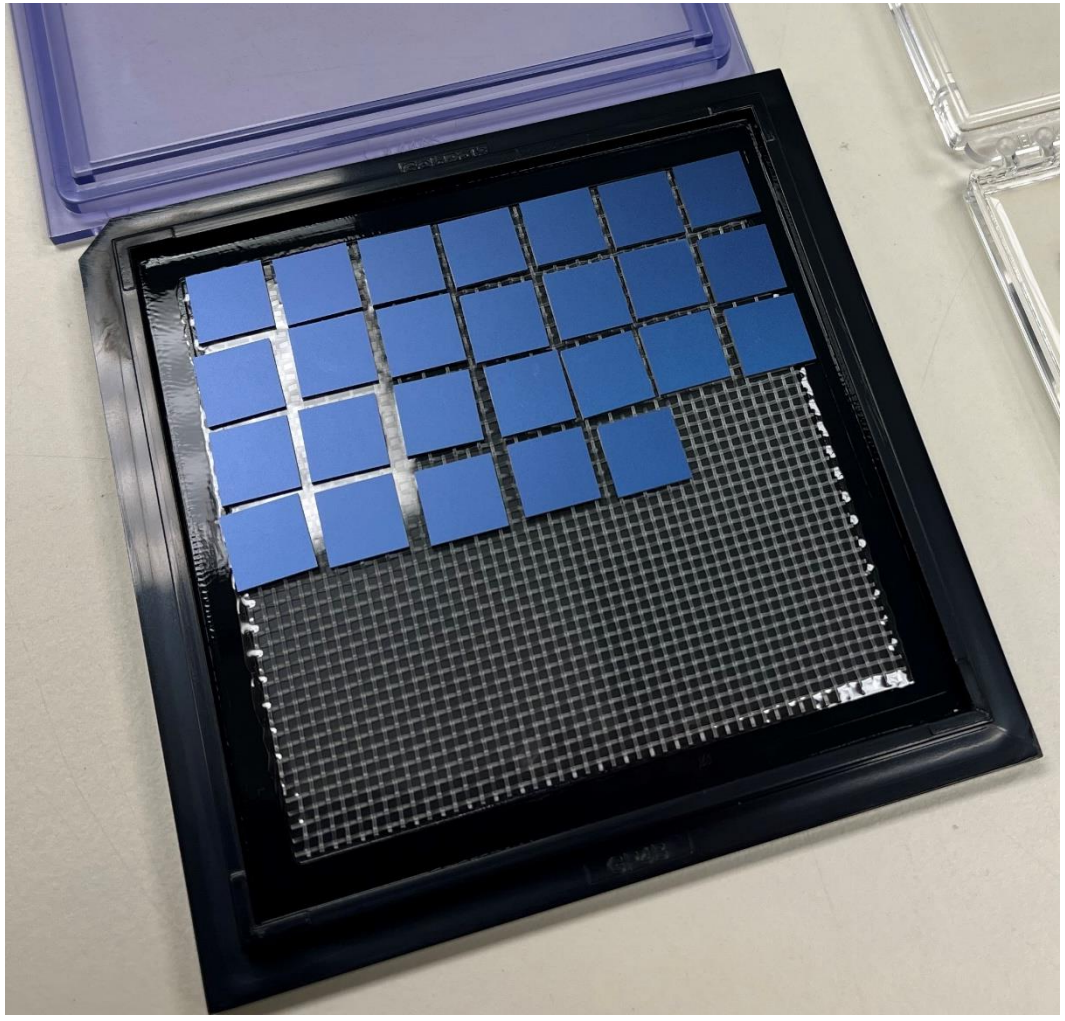
Tape B: UV Dicing Film: FTIR

Sample 1: He+O2 Plasma
Sample 2: He+H2 Plasma
Sample 3: He+O2+H2 Plasma



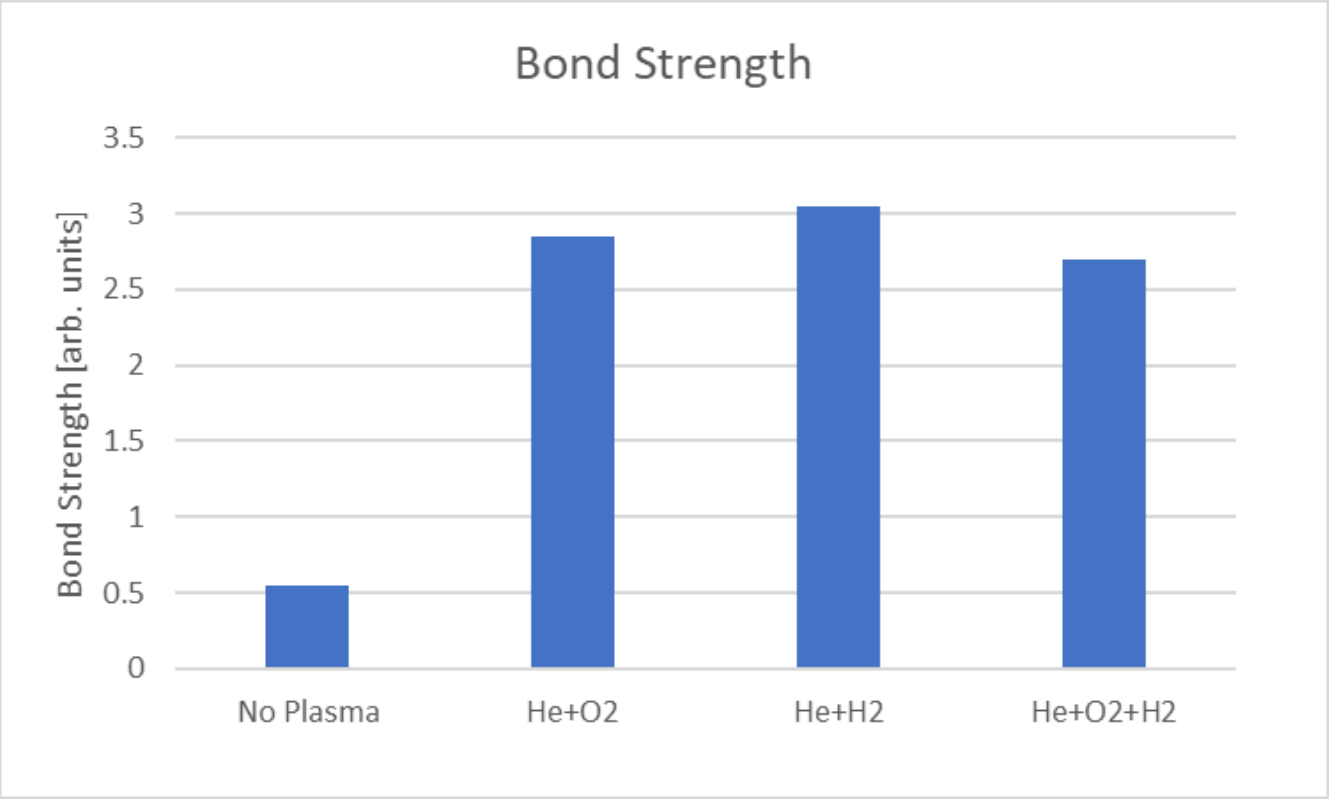
- Hydrocarbons are present on coupons after material contact
- UV Dicing Tape also contained carbonyl peak, which is not unexpected for this type of film
- Hydrocarbon and Carbonyl peaks significantly reduced or eliminated post-treatment
- Metal oxides present after aging in oxygen environment

Confirmation bonding test



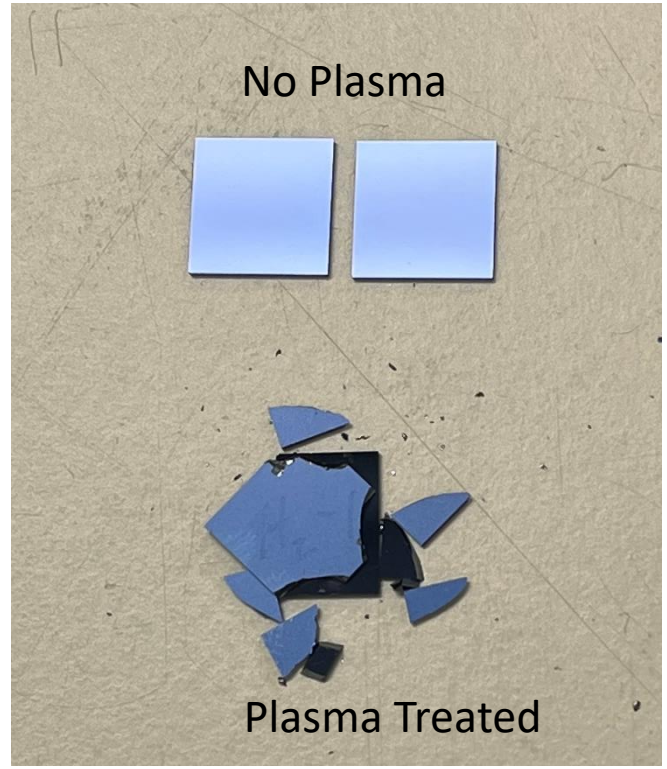
- Contaminated SiO2 coupons were plasma treated, direct bonded, and tested for bond strength.

Confirmation bonding results



- Contaminated sample without plasma treatment separated with little force
- Plasma cleaned samples were bonded at least 5x – 6x stronger
- Plasma cleaned samples broke before delamination (bulk failure)

Results after bond strength test



Conclusions

- WCA and FTIR data confirms all materials transferred some residues to FTIP surfaces including hydrocarbons, silicones, and in one case, residues containing carbonyl group.
- ONTOS atmospheric plasma was able to significantly reduce or eliminate all transferred residues
- Effective residue cleaning was confirmed using SiO2 direct bonding tests.
- These results can potentially be utilized for direct D2W bonding applications.

Thank you for your attention!

Please visit Booth #24 (Ontos/MicroTest)
for more information