Multihole Atmospheric Pressure Plasma Jet: Development and Applications

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Introduction: Atmospheric pressure plasma

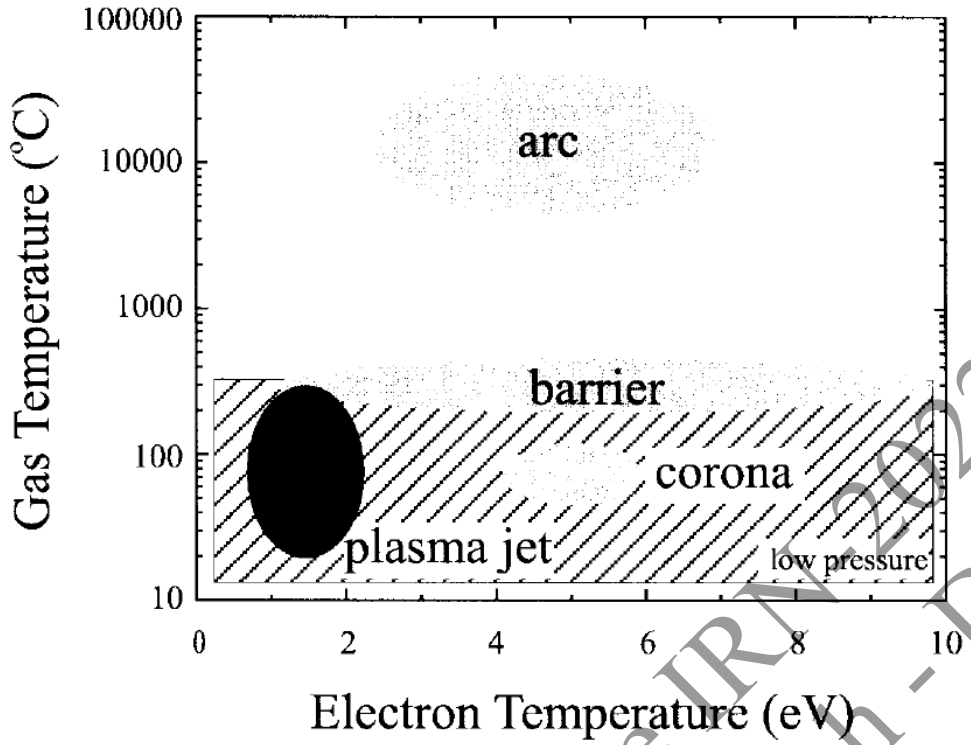


Fig. 1. Comparison of the gas and electron temperatures for different atmospheric-pressure plasmas versus low-pressure plasmas.
Ref: Schütze er al. 1998

Table 1. Species detected in atmospheric pressure plasma

Air plasma generated species	Density (cm^{-3})
Superoxide (O_2^{*-})	10^{10} - 10^{12}
Hydroxyl (OH^*)	10^{15} - 10^{17}
Hydrogen Peroxide (H_2O_2)	10^{14} - 10^{16}
Ozone (O_3)	10^{15} - 10^{17}
Nitric Oxide (NO)	10^{13} - 10^{14}
UV radiation, energetic ions, charged particles etc.	

Introduction: APPJ vs DBD

- Atmospheric pressure plasma jet (APPJ)

Fig. 2. First prototype of atmospheric pressure plasma jet. Photography by Ruttiya Hong-tong (2009)

- Dielectric barrier discharge (DBD)

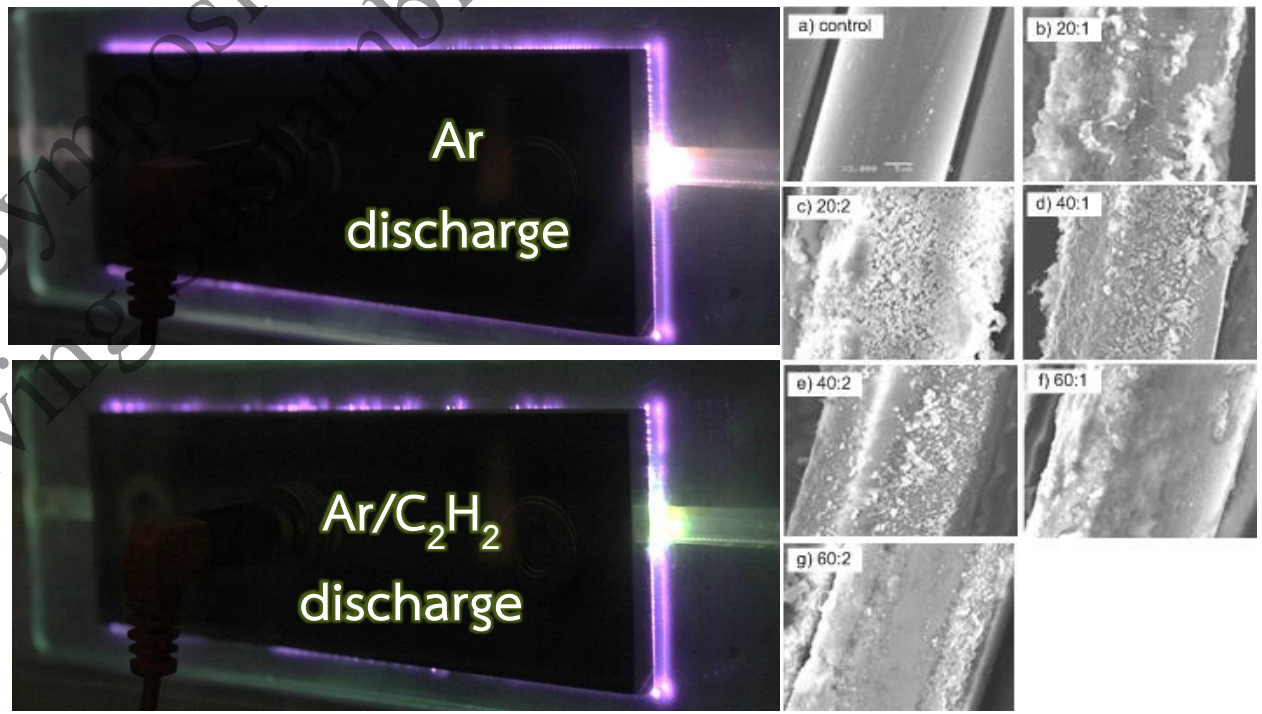
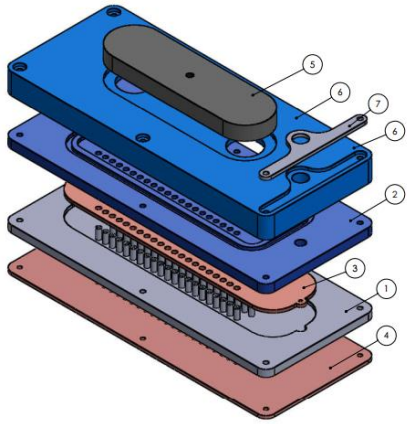
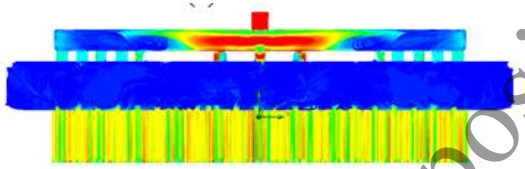


Fig. 3. The DBD system used for treatment and carbon coating of textile. Photography by A. Chingsungnoen (2010)

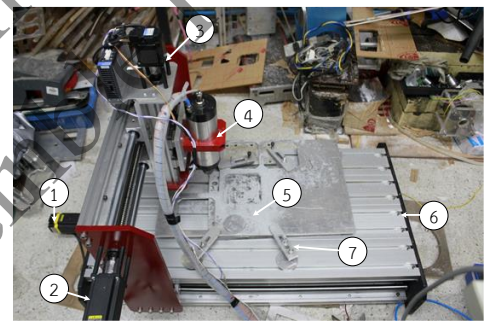
Development of multihole-APPJ: Production process



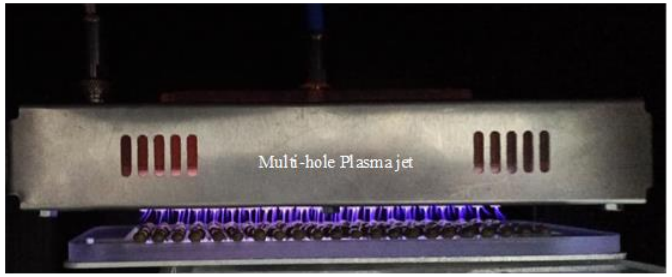
Design electrodes and gas distributor



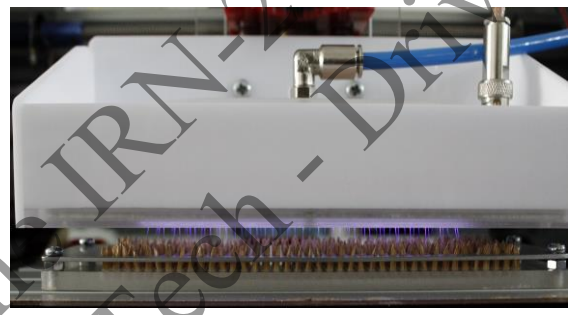
Simulate gas flow



Machine components



Assembly and test



Optimize conditions

Applications

Fig. 4. Production process of multihole-APPJ

Development of multihole-APPJ: Power supply (V.1)

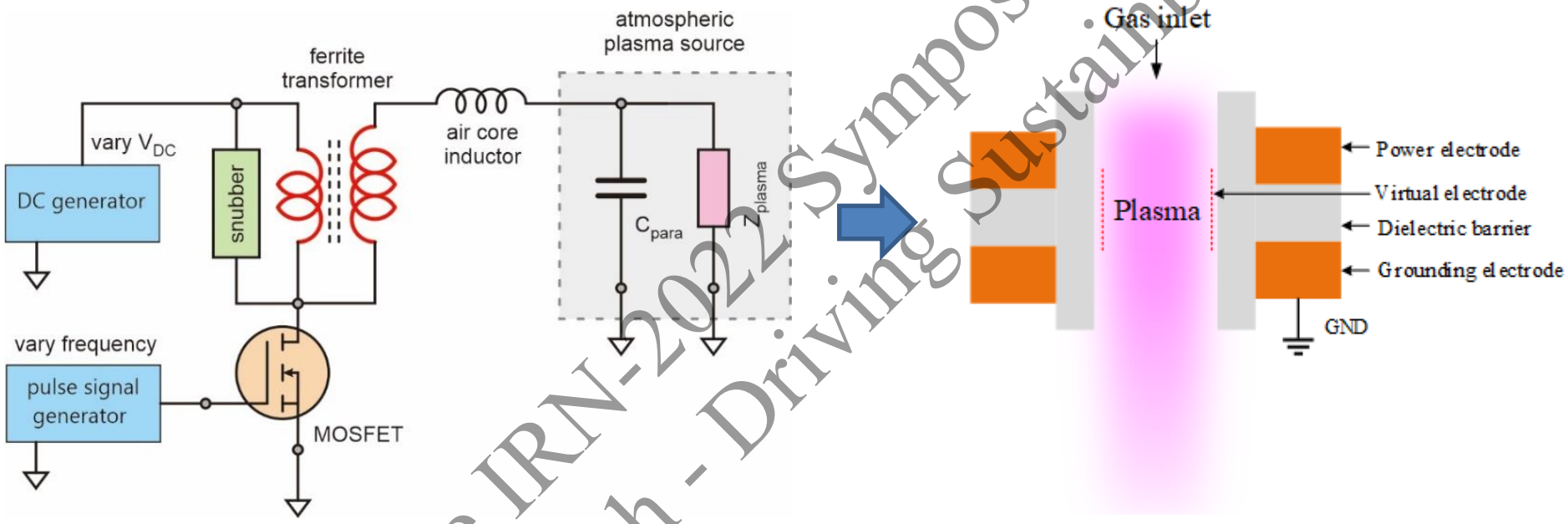
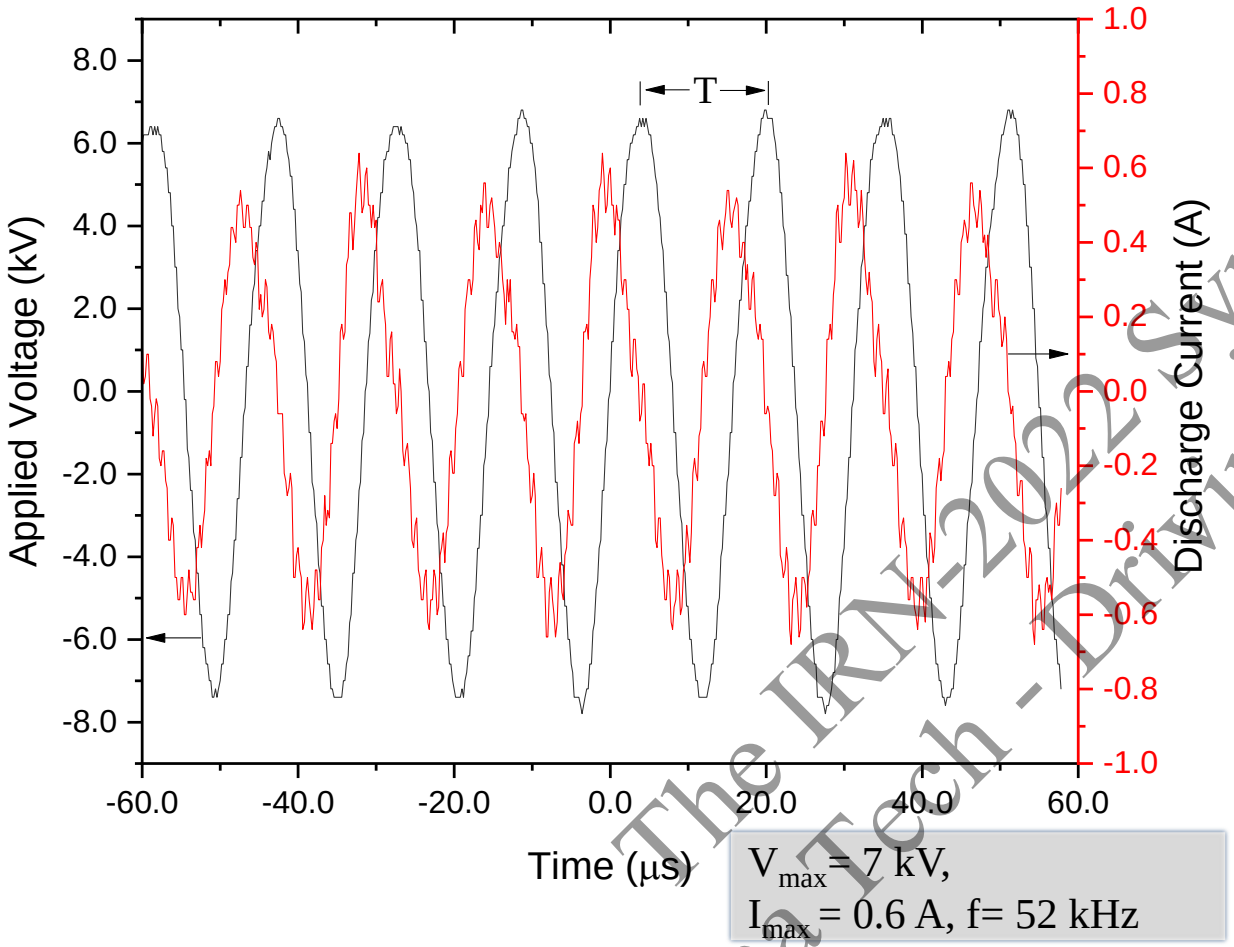


Fig. 4. Flyback topology power supply design

I-V characteristic of plasma source



V_{max} = 7 kV,
I_{max} = 0.6 A, f= 52 kHz

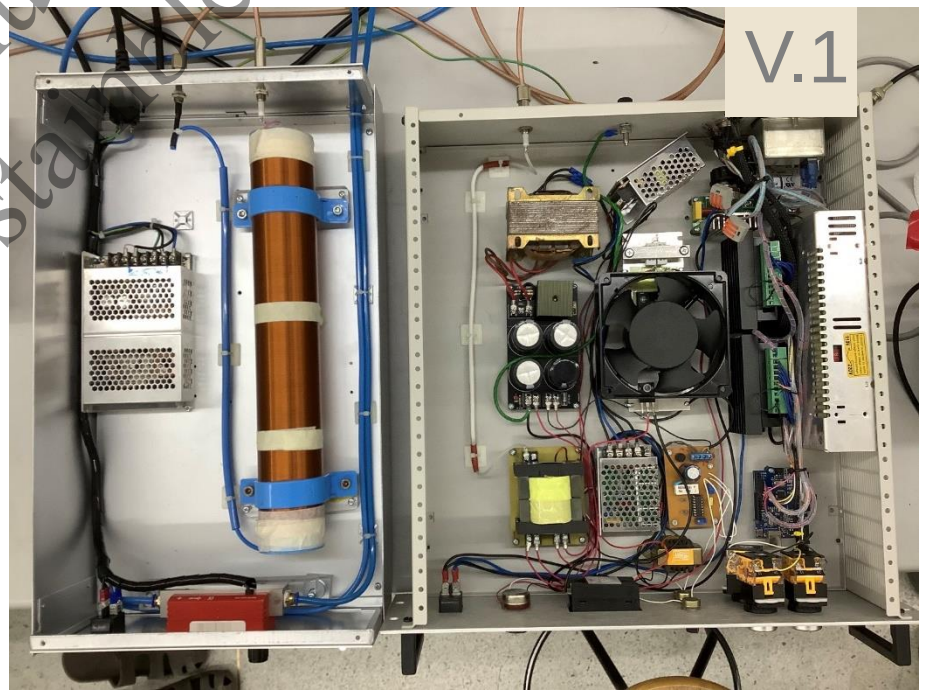


Fig. 5. Voltage and current signals output from the plasma source

Testing with different argon flow rate

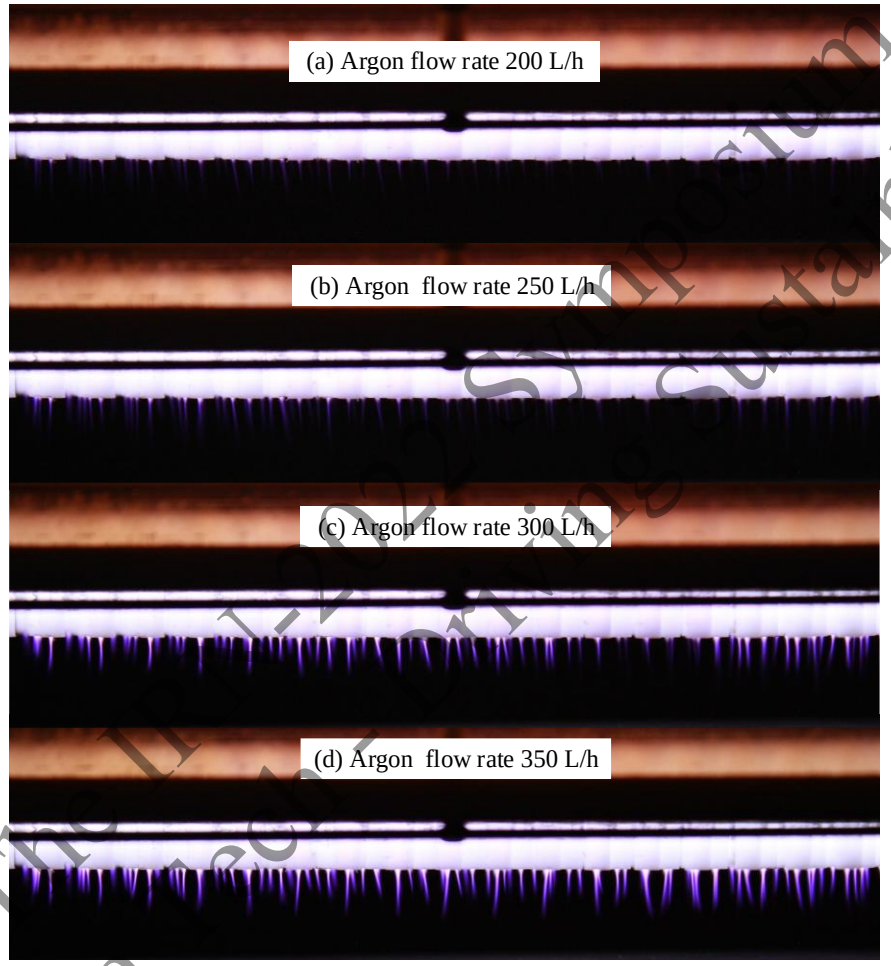
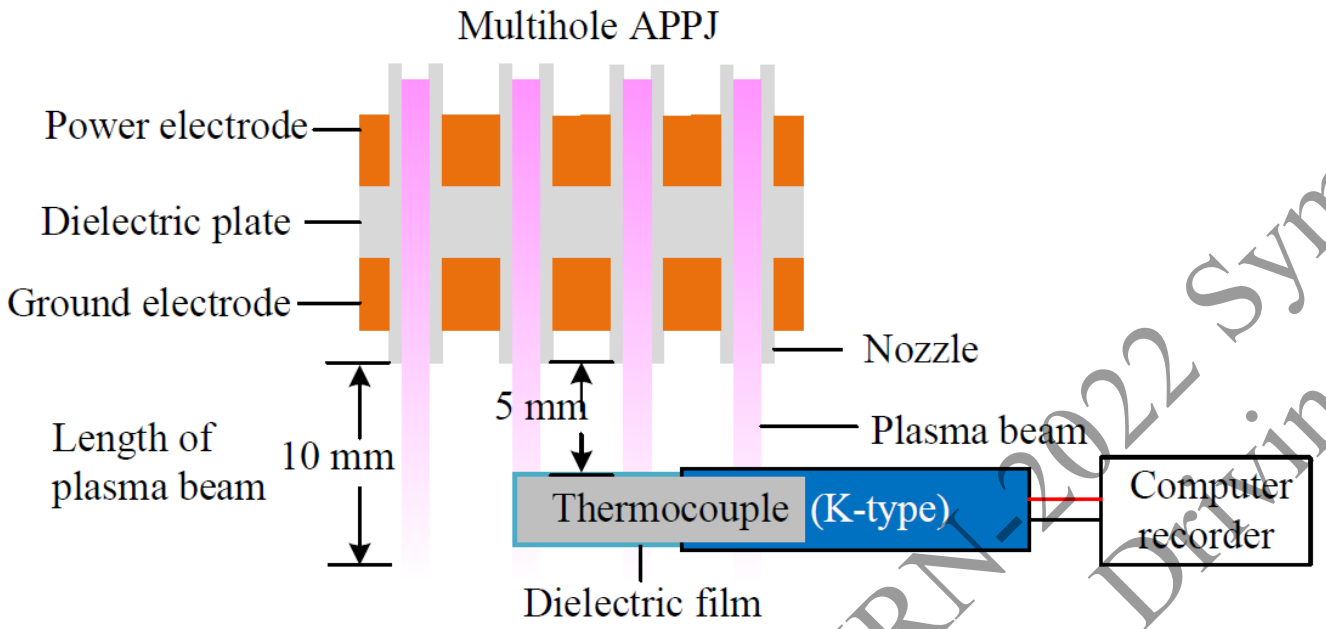


Fig. 6. Plasma beam length as a function of argon flow rate

Temperature of plasma beam



Srakaew, K.et al., Processes 2021, 9, 1134.

Fig. 7. Schematic diagram of the multihole plasma jet with temperature measurement (not to scale)

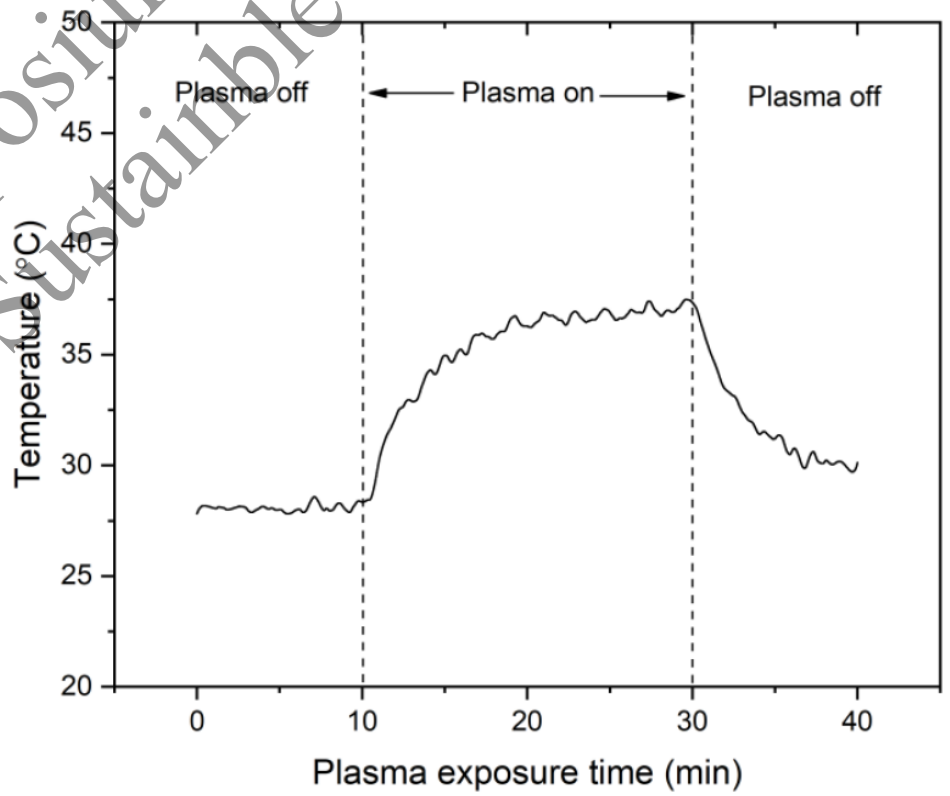
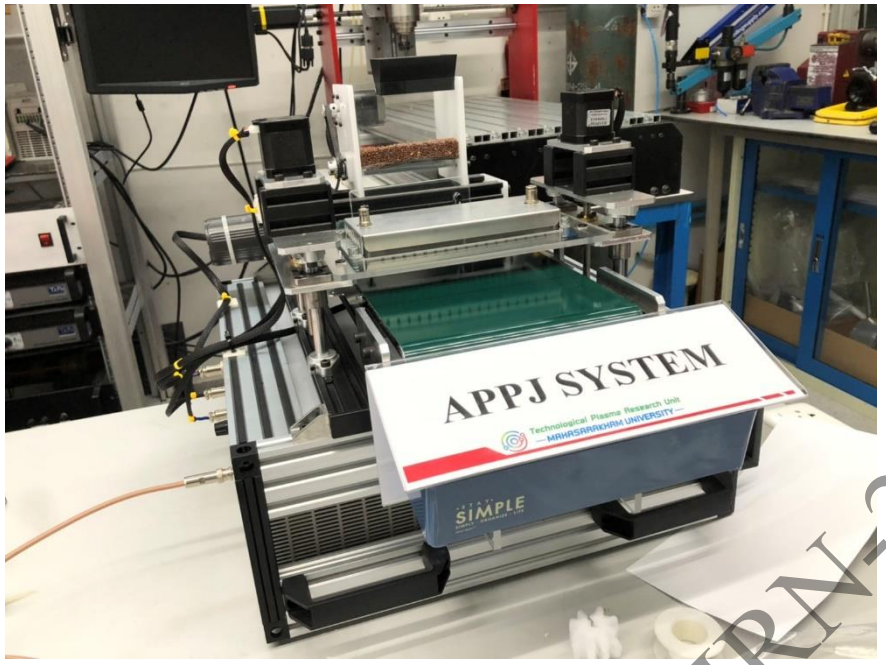
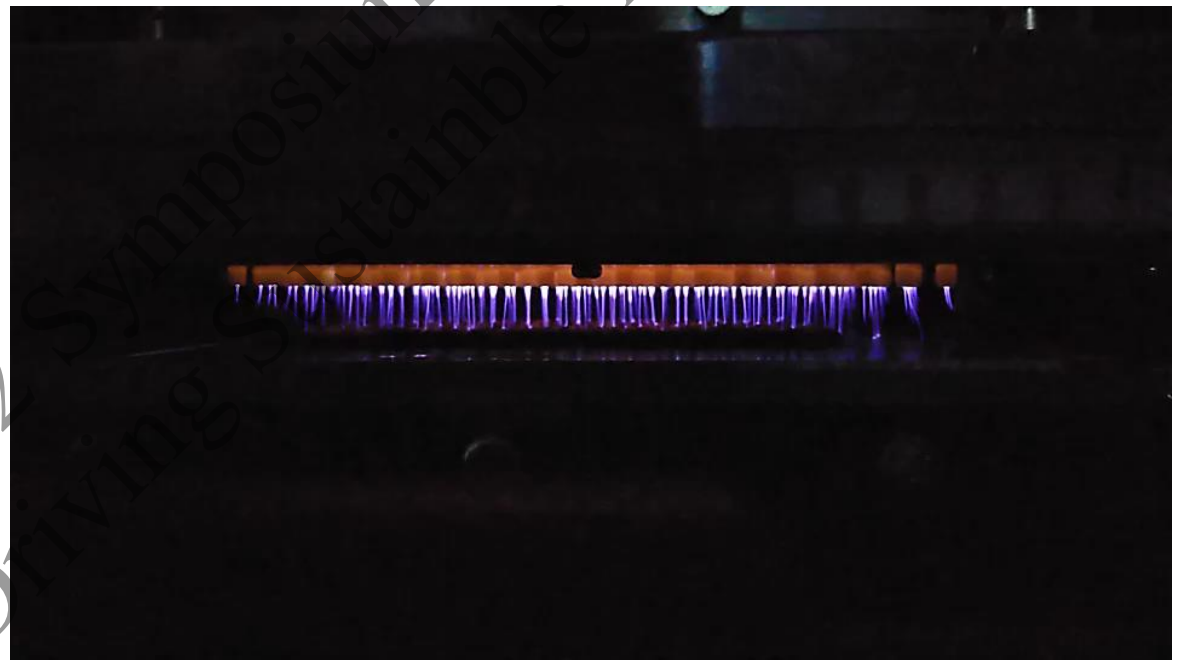


Fig. 8. The temperature on the probe as a function of the plasma exposure time.

Application for seed treatment



a) Multi-hole plasma jet



b) Clip VDO during treatment process

Fig. 9. Atmospheric pressure plasma jet system applied for surface modification

Application for seed treatment

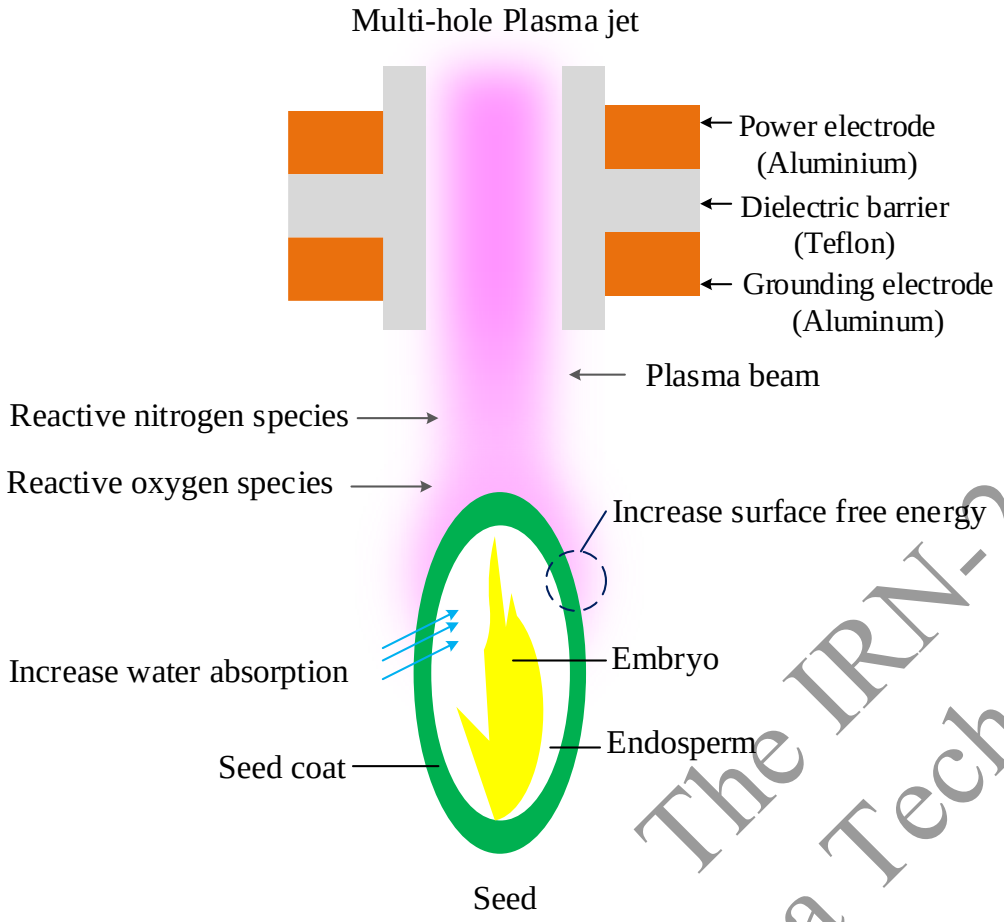


Fig. 10. Cartoon used for describing effect of plasma jet on seed

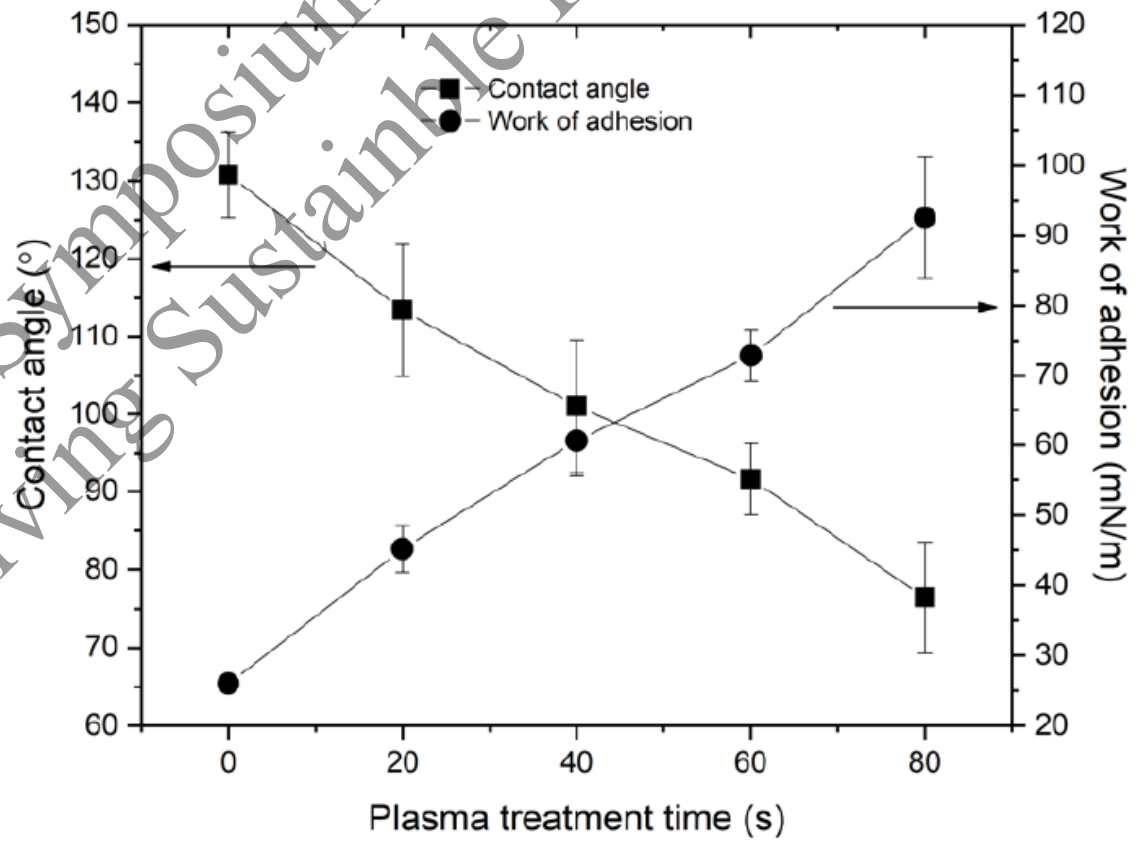


Fig. 11. Contact angle and work of adhesion as a function of the plasma treatment time of broccoli seeds.

Application for seed treatment

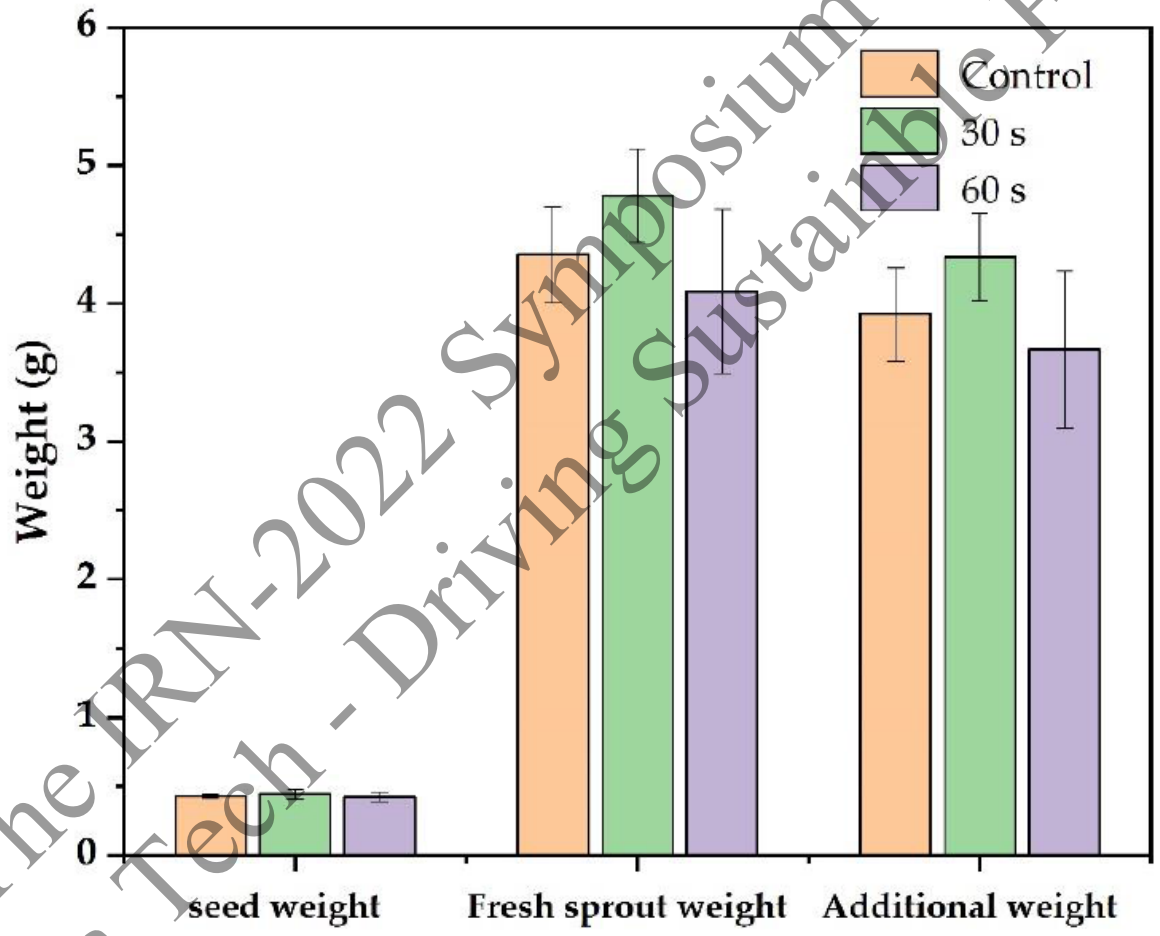


Fig. 12. Comparison of the weight of sprouts of treated and untreated broccoli seeds after seven days of cultivation.

Multihole APPJ design for large area treatment

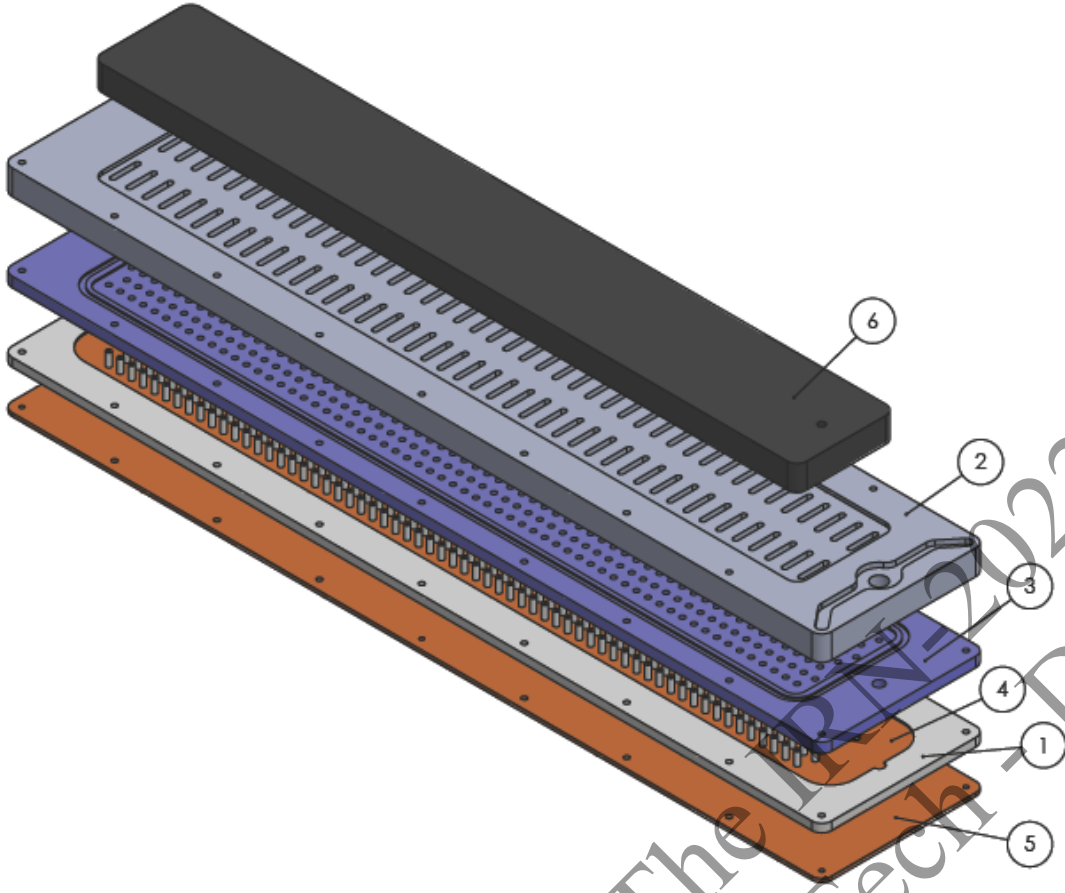
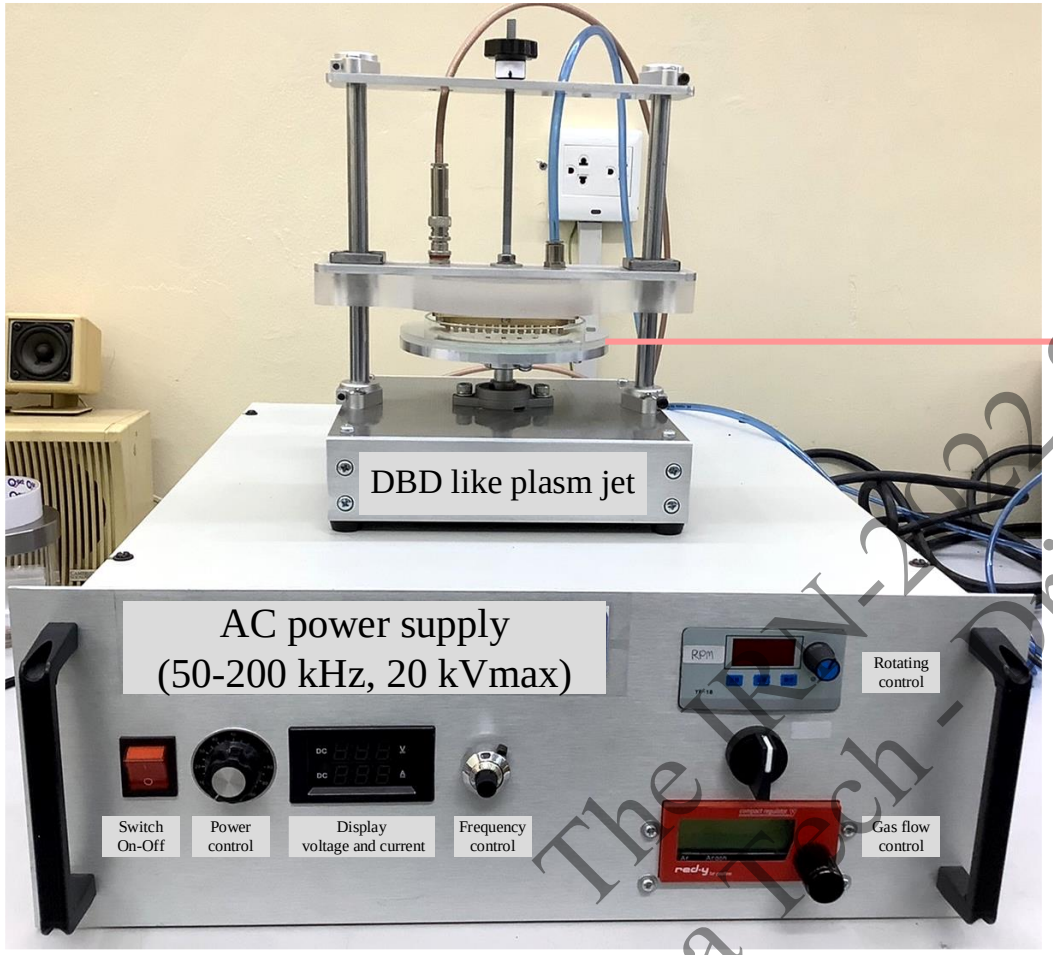


Fig. 13. Multihole-APPJ assembly for large area treatment (427 holes)

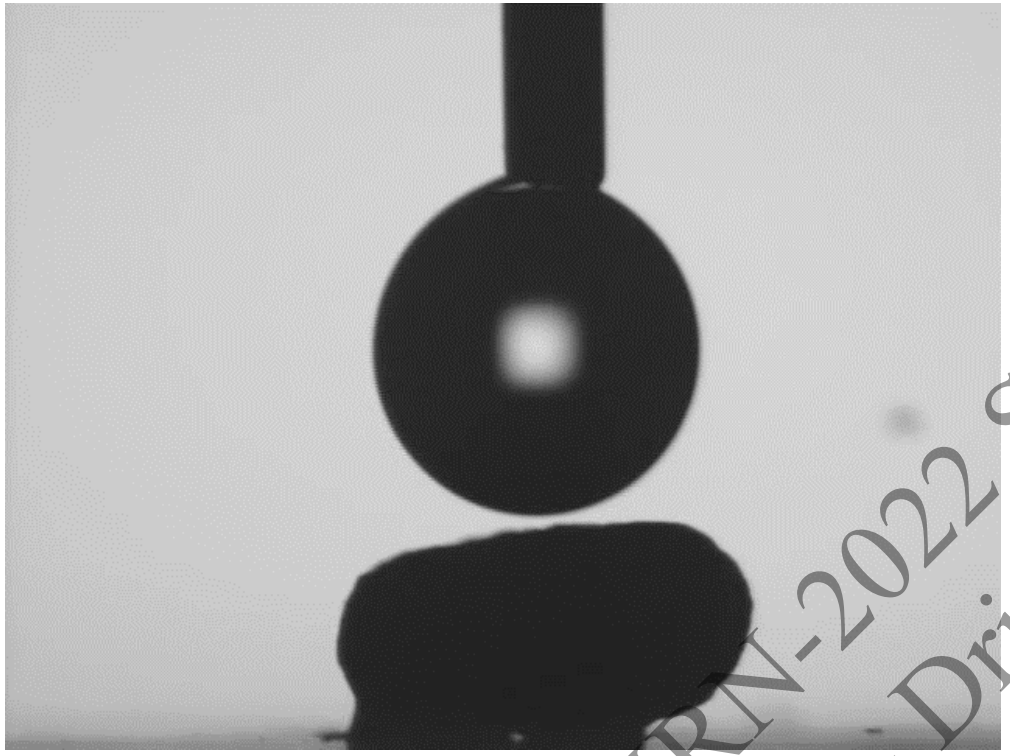
Fig. 14. Prototype of multihole-APPJ device

New design of DBD-like plasma jet for seed treatment



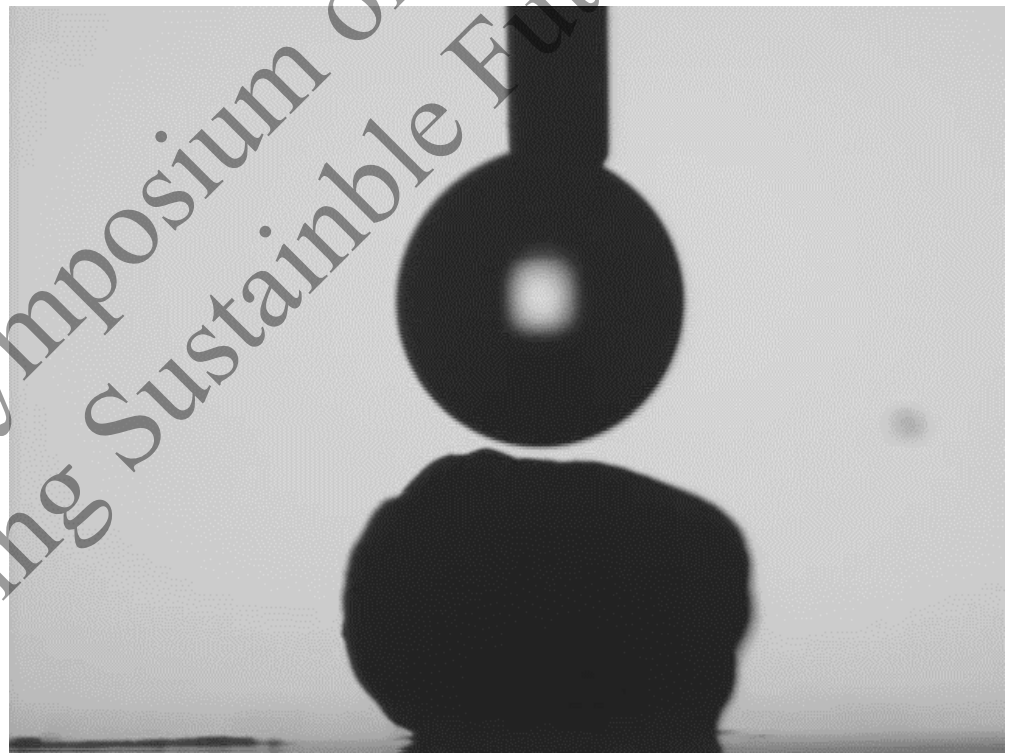
- Short treatment time with high density plasma
- Suitable for seed treatment

Fig. 15. Photograph of DBD-like plasma jet system and clip VDO during treatment



Control

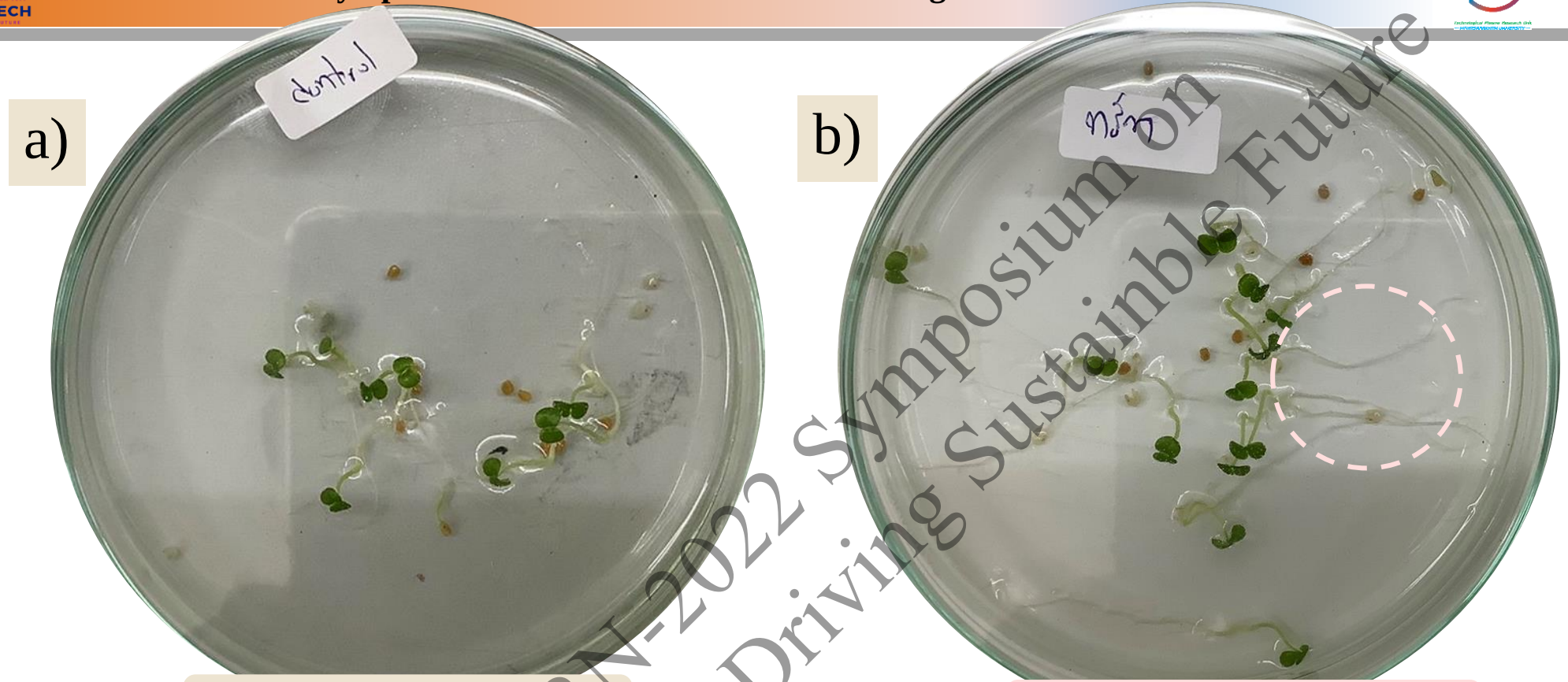
Treatment time (s): 0
Absorption time (s) : 55



Plasma treatment for 60 s

Treatment time (s): 30
Absorption time(s) : 3

Fig. 16. Measurement contact angle during drop of water into *Andrographis paniculata* seed



Control

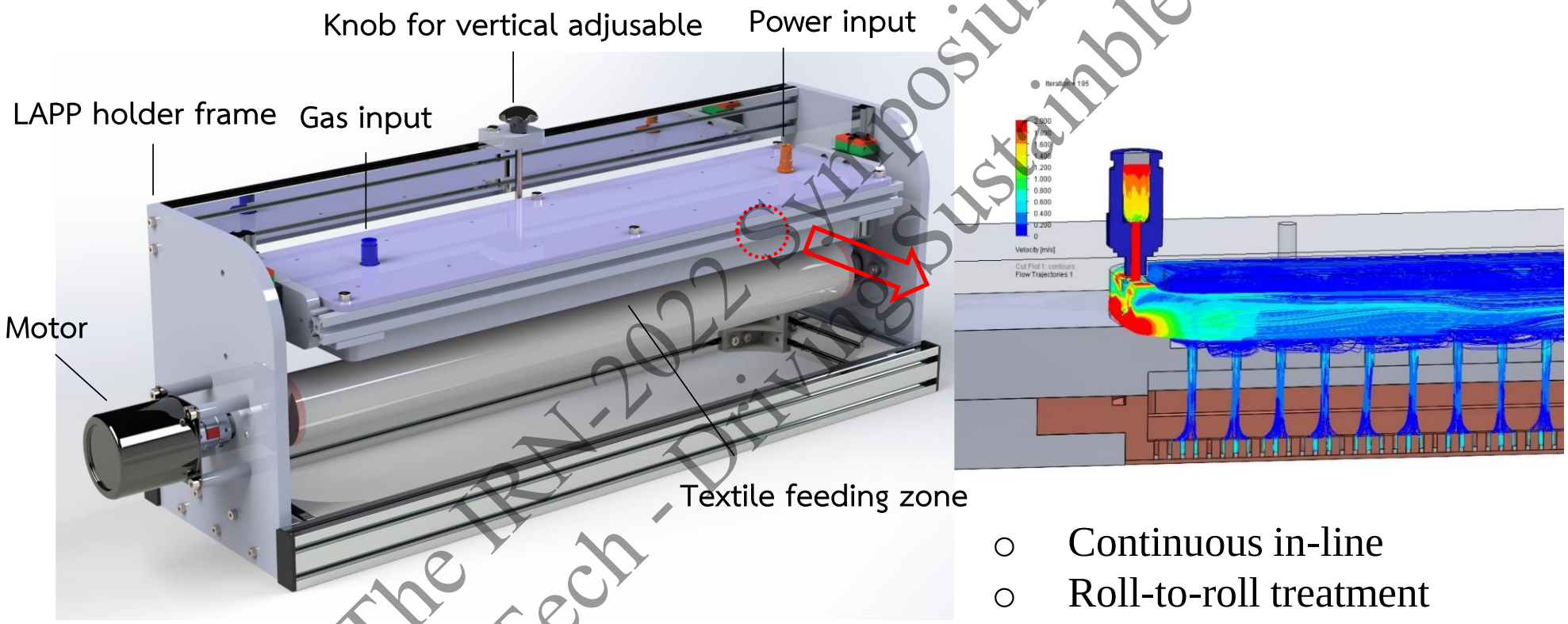
Total number of seeds : 20
Number of germinated seeds : 8
Germination rate (%) : 45

Plasma treatment for 60 s

Total number of seeds : 20
Number of germinated seeds : 12
Germination rate (%) : **60**

Fig. 17. Comparing of sprout of *Andrographis paniculate* after 15 days of cultivation a) Control b) Treatment

New version of multihole-APPJ for Roll-to-Roll treatment



- Continuous in-line
- Roll-to-roll treatment

Fig. 18. Linear -APPJ

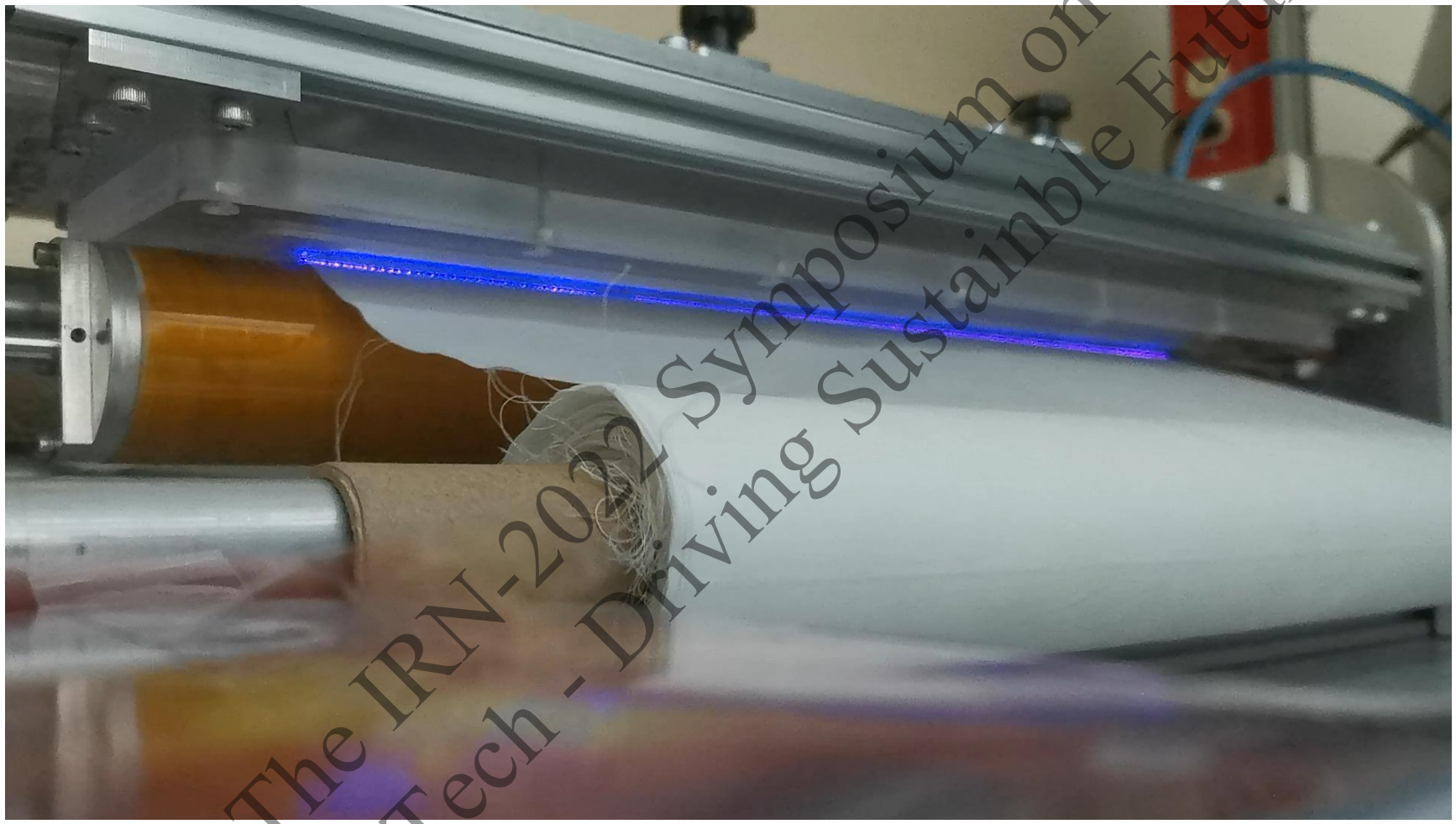


Fig. 19. Side view during the textile treatment with Linear -APPJ

Effect of plasma treated on textile

Treated : February 15, 2021
Measured : March 5, 2021

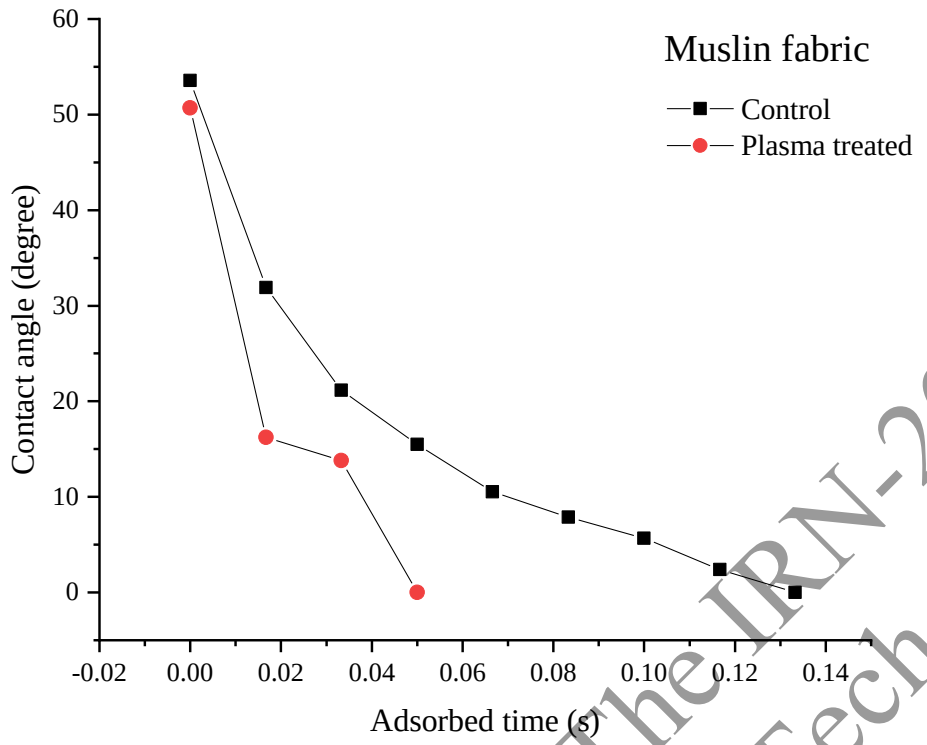


Fig. 21. Water contact angle as a function of time after droplet into muslin fabric

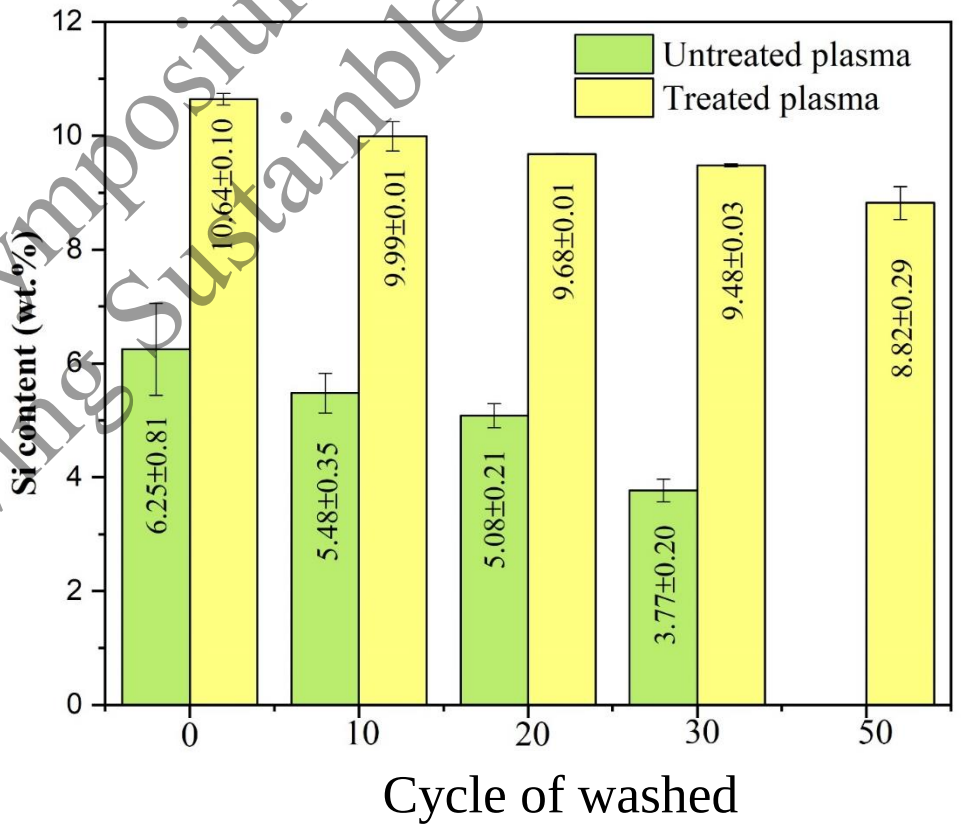


Fig. 22. Comparing the Si content in muslin fabric treated and untreated by Linear-APPJ

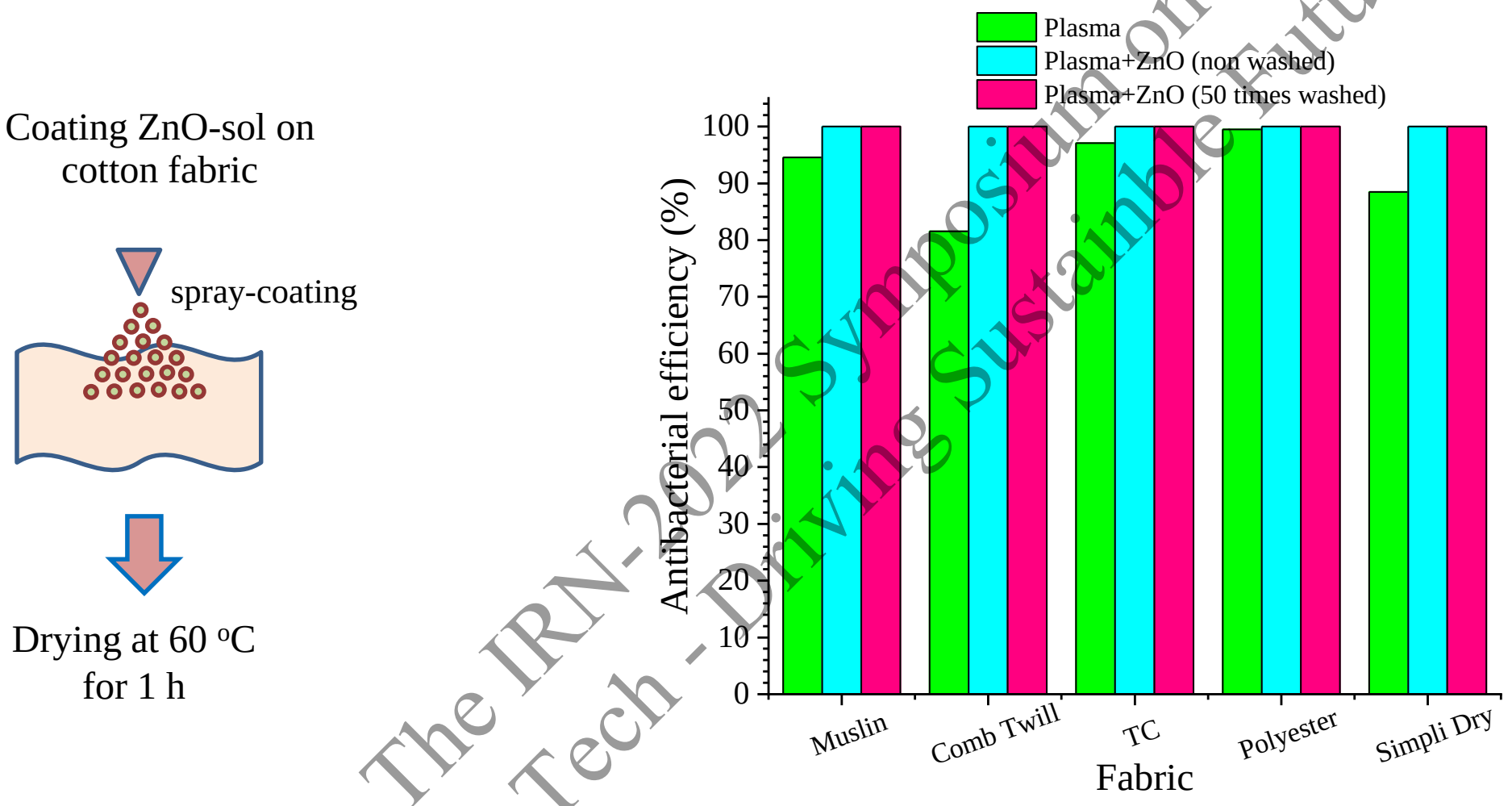


Fig. 23. Textiles treated by Linear-APPJ and coated with ZnO nanosolution can exhibit antibacterial efficiency

Conclusions

My research topics focused mainly on the development of atmospheric pressure plasmas based on the hybrid of DBD and plasma jet. Examples of applications for these devices include:

- Plasma agriculture to enhance growth and germination
- Plasma textiles. The main purpose of these designs is surface activation, followed by coating with precursors of nano-solutions for hydrophobic/hydrophilic properties.