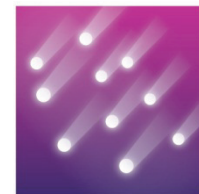




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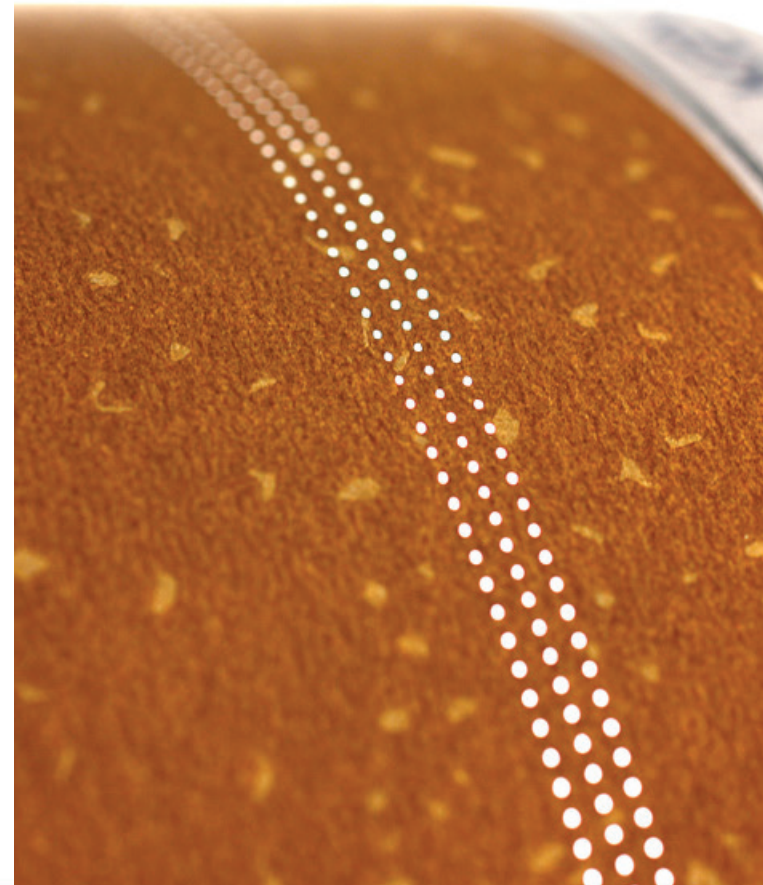


# PLASMA PERFORATION OF TIPPING PAPER: SELECTED BENEFITS FOR CIGARETTE CONSUMPTION

Michael LINDNER, TANNPAPIER GmbH, AUSTRIA  
Renata Raunić Vadanjel, TDR d.o.o.

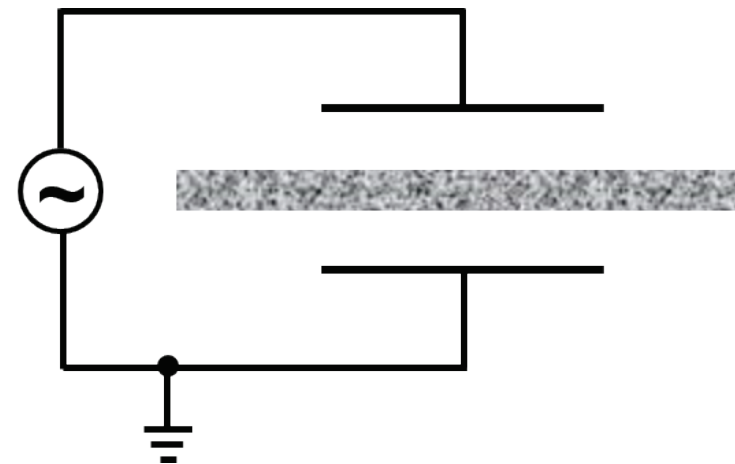
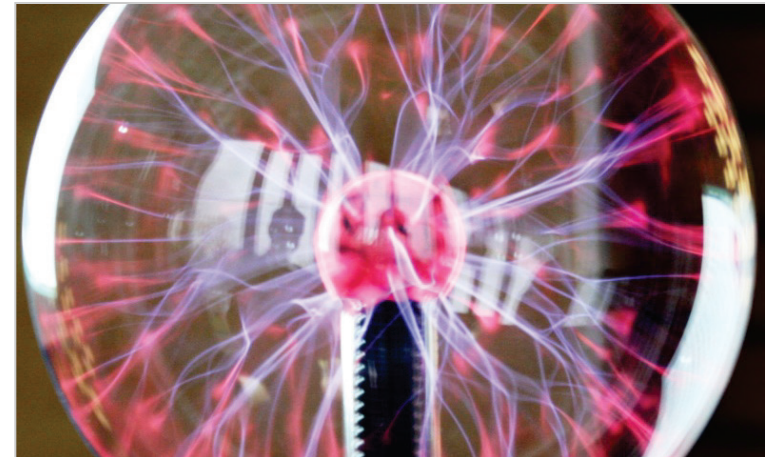
# TIPPING PERFORATION (FILTER VENTILATION) METHODS

- Traditional techniques:
  - Electrostatic perforation (EP; offline)
  - Laser perforation (LP; offline & online)
- Advanced technology to realize pre-perforated Tipping Paper: **Plasma Perforation (PP)** to improve the
  - stability of cigarette properties
  - smoke yields reduction capacity
  - taste of cigarette smoke



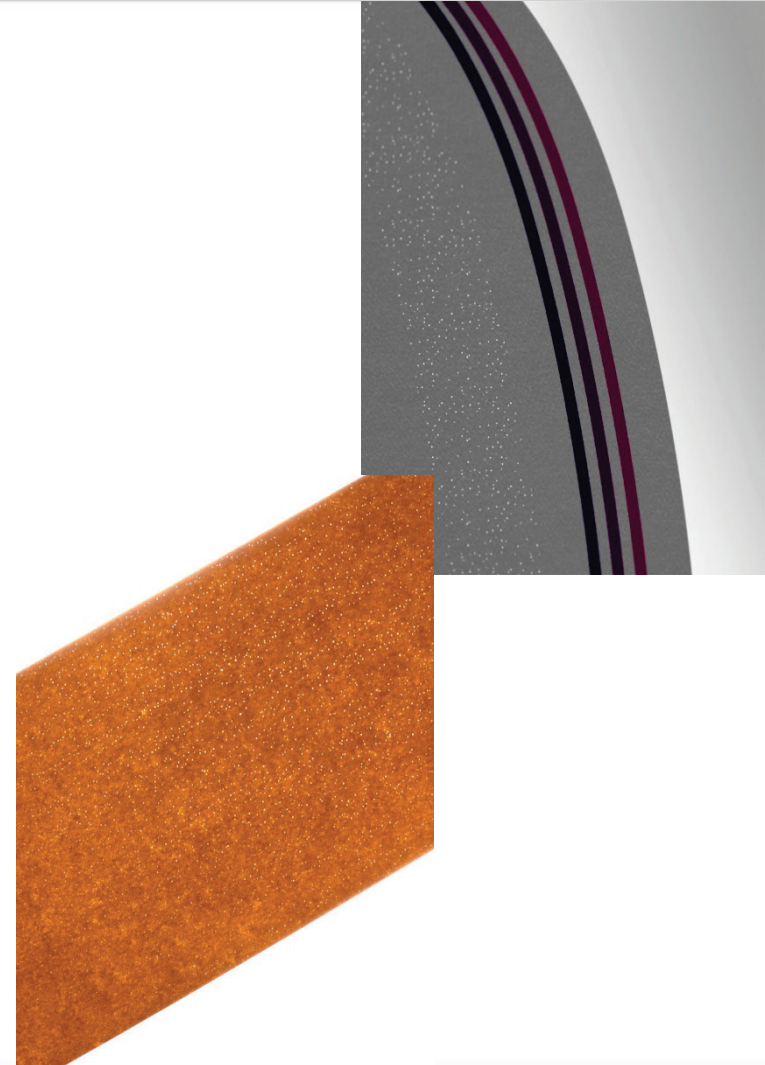
# PLASMA PERFORATION: TECHNICAL BACKGROUND

- Plasma is generated by high-voltage dielectric barrier discharges (DBDs) which are self-sustained electrical micro-discharges accompanied by the emission of short light pulses from the discharge gap
- DBD structures are characterized by insulating layers inside the discharge gap
- Materials for dielectric barriers are glass, ceramics, polymer films or cellulose (e. g. paper)



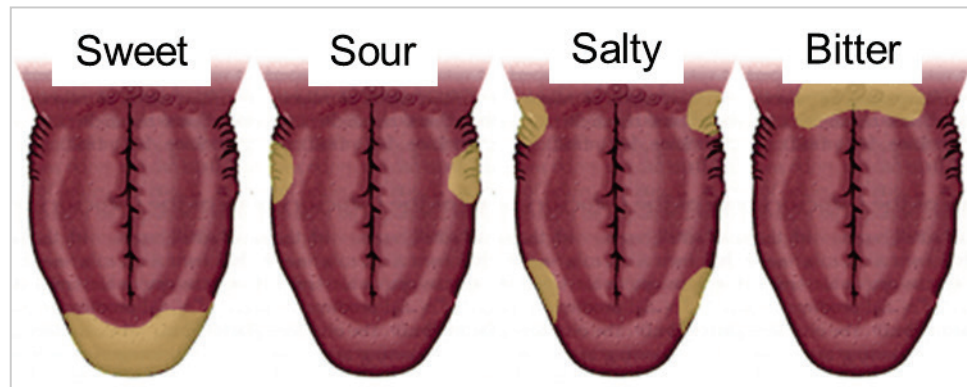
# PLASMA PERFORATION: LOW-TEMPERATURE AND INERT GAS

- Dielectric barrier: **Tipping Paper**
- Generation of **invisible** perforation holes by means of **material evaporation** (no burning process = no pyrolytic side effects)
- Perforation in bands or on the **entire** Tipping Paper **surface**
- Realization of **small hole diameters** down to 10  $\mu\text{m}$  together with **high hole densities**



# SENSORY PROPERTIES OF CIGARETTE SMOKE

- Cigarette smoke deals with taste, smell and feel / touch in addition to the physiological effect of nicotine
- 4 primary tastes detected on the tongue and pharynx (besides umami):



- Smoke components like ammonia stimulate specific nerves in the skin of the tongue and top of the mouth → **“tingling” sensation**
- Taste of cigarette smoke is always rather subjective



# CIGARETTE SAMPLES FROM TDR D.O.O. (ROVINJ / CROATIA)

Sample Number	Perforation Type	Permeability [CU]	CoV of Perm. [%]	Hole Diameter [µm]	Open Pressure Drop [mm H <sub>2</sub> O]	CoV of Open PD [%]	Filter Ventilation [%]	CoV of Filter Vent. [%]
1	Plasma	50	2,16	18	107,15	3,65	9,34	6,44
2	Electrostatic	60	5,04	21	110,40	4,50	8,67	8,77
3	Offline-Laser	60	6,56	81	108,75	4,00	7,37	8,83
4	Online-Laser	88	9,58	138	107,3	4,25	8,48	15,25
5	Plasma	100	1,34	23	101,30	2,90	15,71	4,74
6	Electrostatic	120	3,81	30	105,00	3,50	14,85	8,18
7	Offline-Laser	120	5,01	87	102,30	3,55	13,28	8,06
8	Online-Laser	135	6,15	173	102,9	3,50	15,20	12,24
9	Plasma	200	0,26	28	92,50	2,60	27,43	4,19
10	Electrostatic	250	2,14	41	93,80	2,95	26,92	5,59
11	Offline-Laser	250	3,62	85	93,65	3,10	23,72	7,87
12	Online-Laser	251	4,33	169	93,55	3,25	26,55	10,40

- Sample production: American Blend Tobacco, 120 CU banded (LIP) cigarette paper, 24000 CU plug wrap paper
- Adhesive-free area underneath the Tipping Paper is 8 mm wide

# CLASSIFICATION OF CIGARETTE SAMPLES

- Cigarettes are equipped with the same grade of Tipping Paper

- Separation according to the four perforation methods, respectively comprising three levels of air permeability (low, medium, high)

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- Cigarettes of the same permeability level exhibit equal degrees of filter ventilation
- The three permeability levels are marked in the table with different color shades

# SURVEY WITH THE TDR D.O.O. SMOKER PANEL

- 7 candidates, 2 sticks per cigarette quality each
- Evaluation of the individual taste sensations “sweet”, “sour”, “salty” and “bitter” of the cigarette smoke with numbers from 0 to 10 whereby
  - 0... Absolutely no sensation of the specific taste
  - 10... Extremely high sensation of the specific taste
- Additionally, the “tingling” impression is evaluated





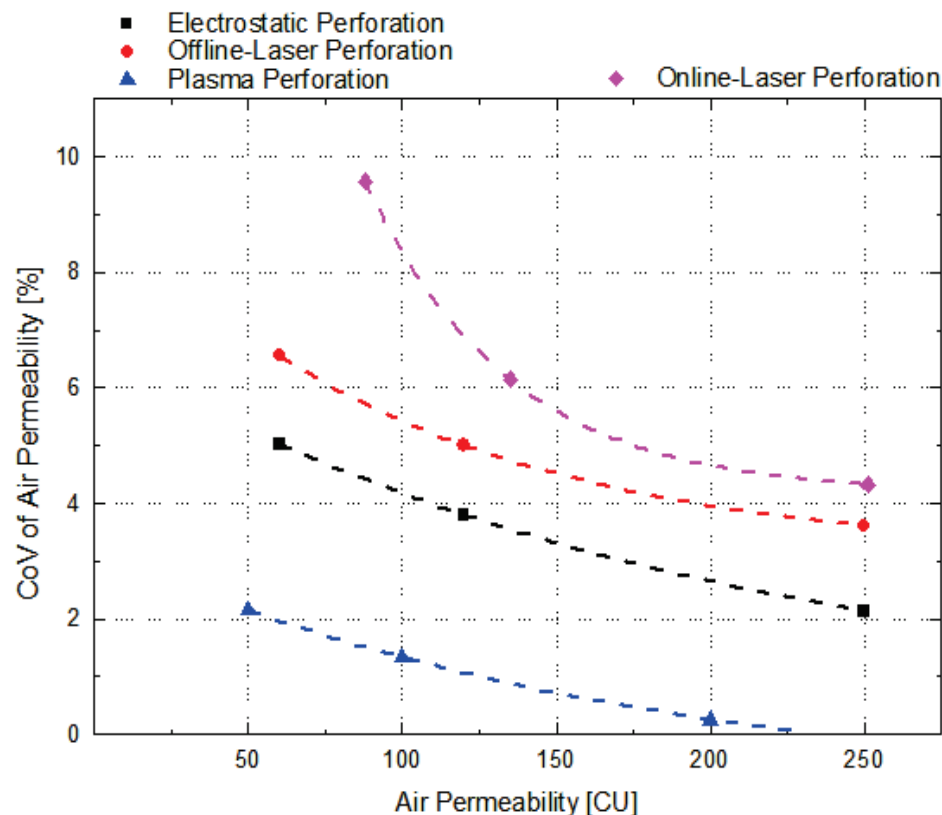


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# EXPERIMENTAL RESULTS

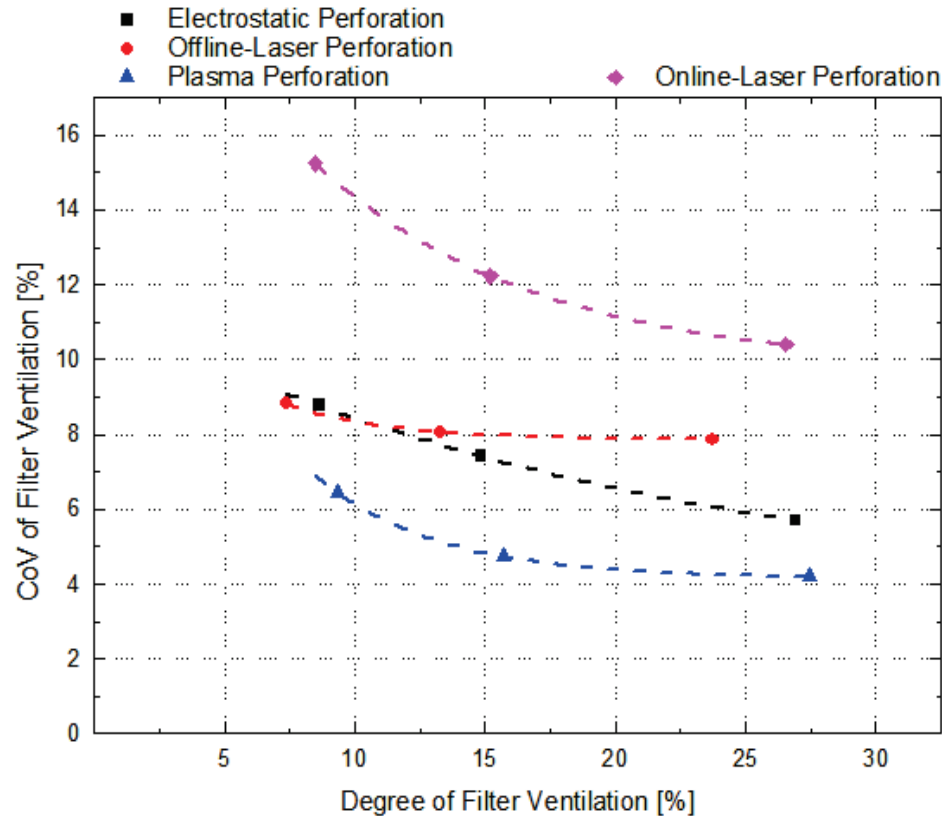


# STABILITY INCREASE OF AIR PERMEABILITY



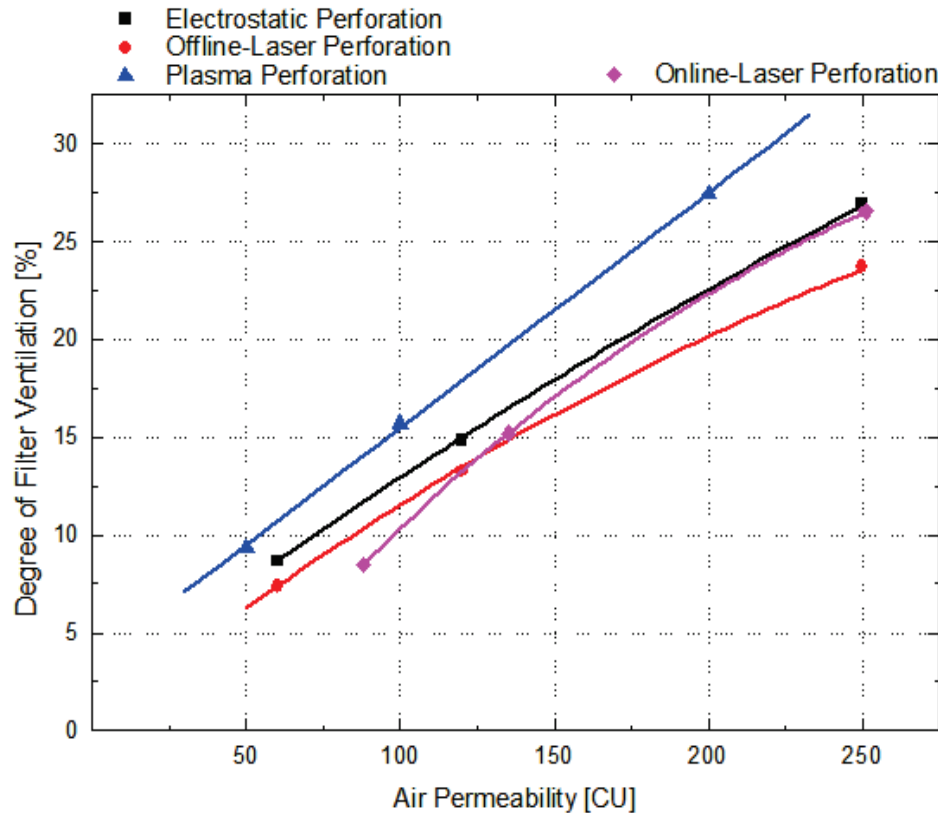
- Results are approximated with exponential functions
- **Highest stability with PP**
- Reason: More homogeneous and stable distribution of the hole size and density with PP than with standard perforation methods

# STABILITY INCREASE OF FILTER VENTILATION



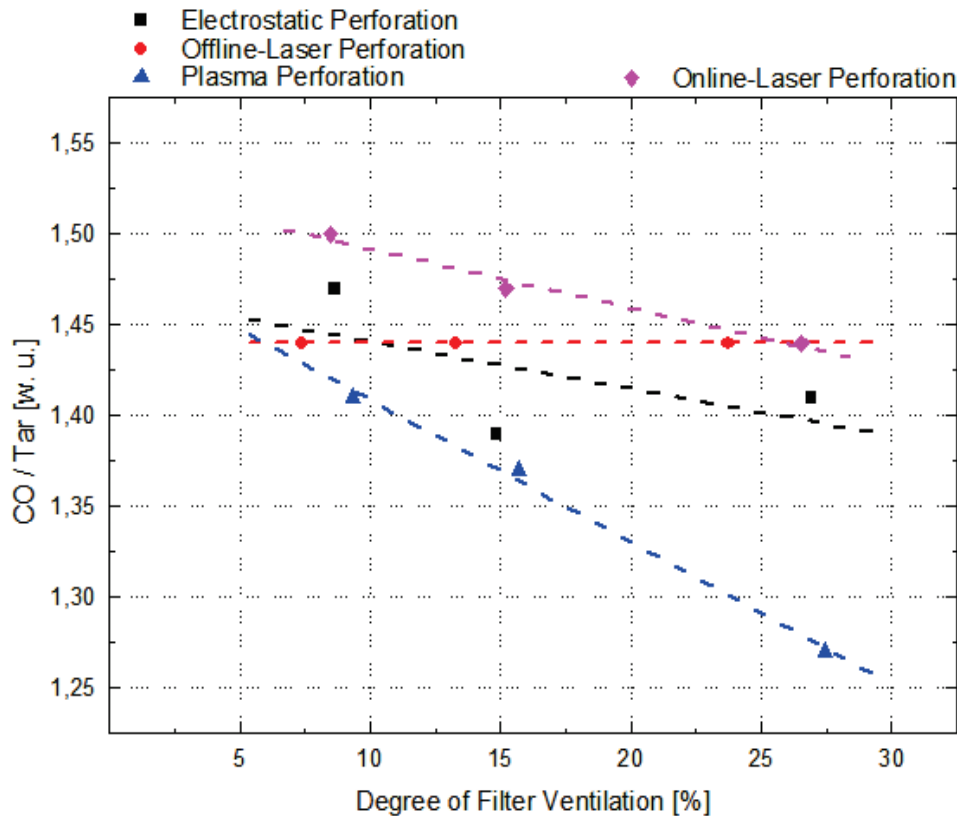
- Stability of the filter ventilation is controlled by the stability of the air permeability
- **Lowest variation (only 5% in average) with PP**
- Relatively high variation (13% in average) with online LP

# HIGHER EFFICIENCY OF FILTER VENTILATION



- At a defined permeability level, the corresponding filter ventilation is larger for PP than for EP and LP (offline & online)
- In average, up to 30% higher filter ventilation can be gained
- EP and LP (offline & online): Non-linear behavior (Darcy's law)
- **PP: Linear relationship**

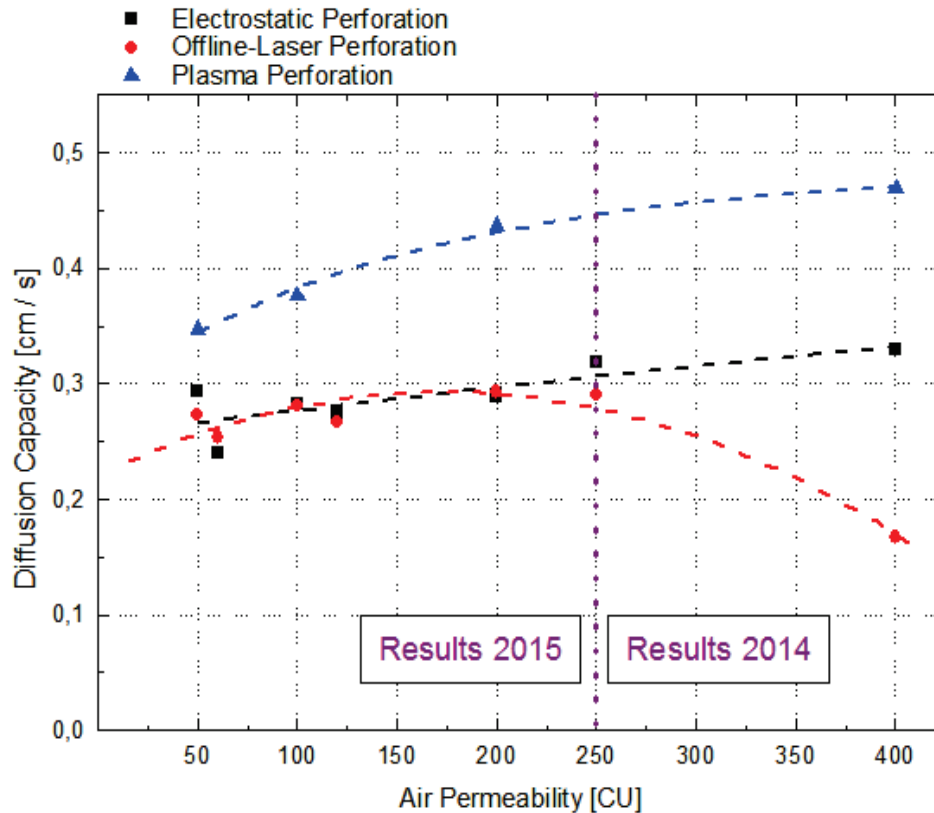
# IMPROVEMENT OF THE CO / TAR RATIO



- At low filter ventilation, EP, offline LP and PP are roughly at the same level
- With increasing filter ventilation, PP deviates towards smaller values
- In average, CO / tar for PP is 7% lower than for EP and LP (offline & online)
- Reason: Diffusion effects

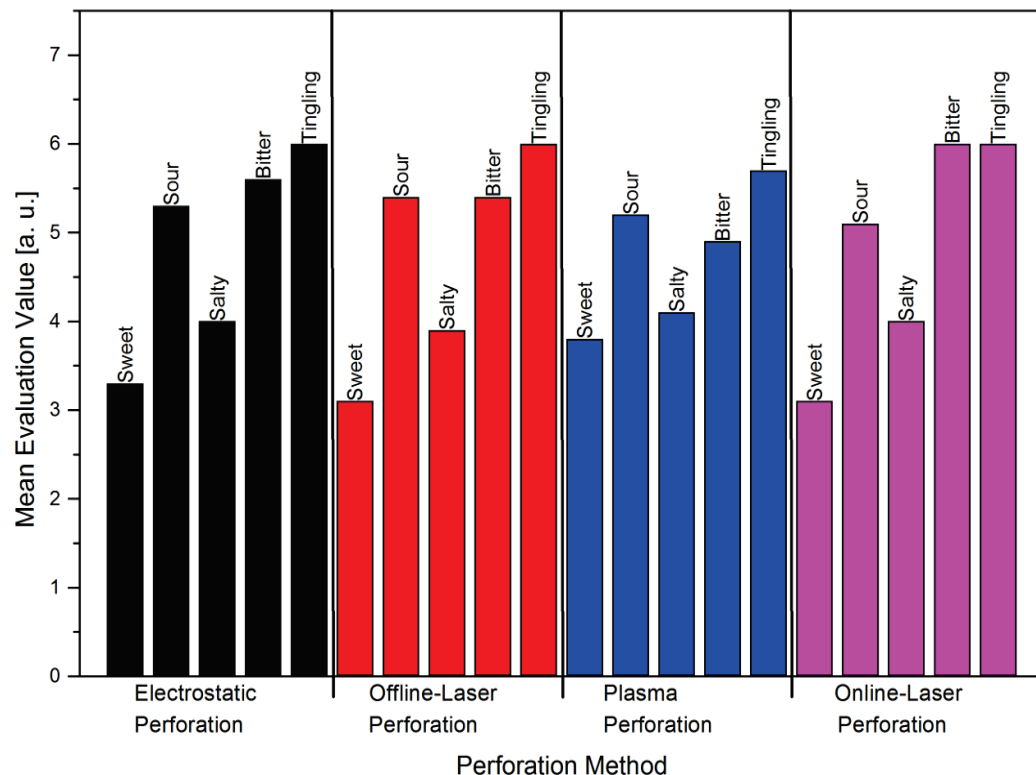


# STRONG DIFFUSION EFFECTS



- According to CRM 77
- No measurable diffusivity for online LP
- Diffusivity drops quickly for offline LP
- Diffusivity grows slowly for EP
- Higher diffusion capacities for PP ending up in a linear increase
- PP delivers 1/3 or 1/4 of the diffusion capacity of non-LIP cigarette paper

# SMOOTHENING THE TASTE OF CIGARETTE SMOKE



- **PP: Sweet increases, while bitter decreases**
- Reason:  
Homogeneously diluted smoke inside the mouth  
→ less irritating influence on the rear center section of the tongue
- Similar effect when switching from online-laser to offline perforation

# BENEFITS CONFIRMED BY TESTS WITH COMMERCIAL CIGARETTES



- Example 1 – Regular cigarette brand produced by an European manufacturer:
  - 450 CU offline LP (standard product): CO / tar = 1,43  
nicotine / tar = 0,074
  - 450 CU PP: CO / tar = 1,29 (-10%)  
nicotine / tar = 0,078 (+5%)
- Example 2 – Commercial test cigarettes produced by a Chinese manufacturer:
  - 200, 250 & 300 CU offline LP: CO / tar = 0,96; 0,95 & 0,93  
nicotine / tar = 0,094; 0,093 & 0,097
  - 200, 250 & 300 CU PP: CO / tar = -3%  
nicotine / tar = +1%

# BENEFITS CONFIRMED BY TESTS WITH COMMERCIAL CIGARETTES

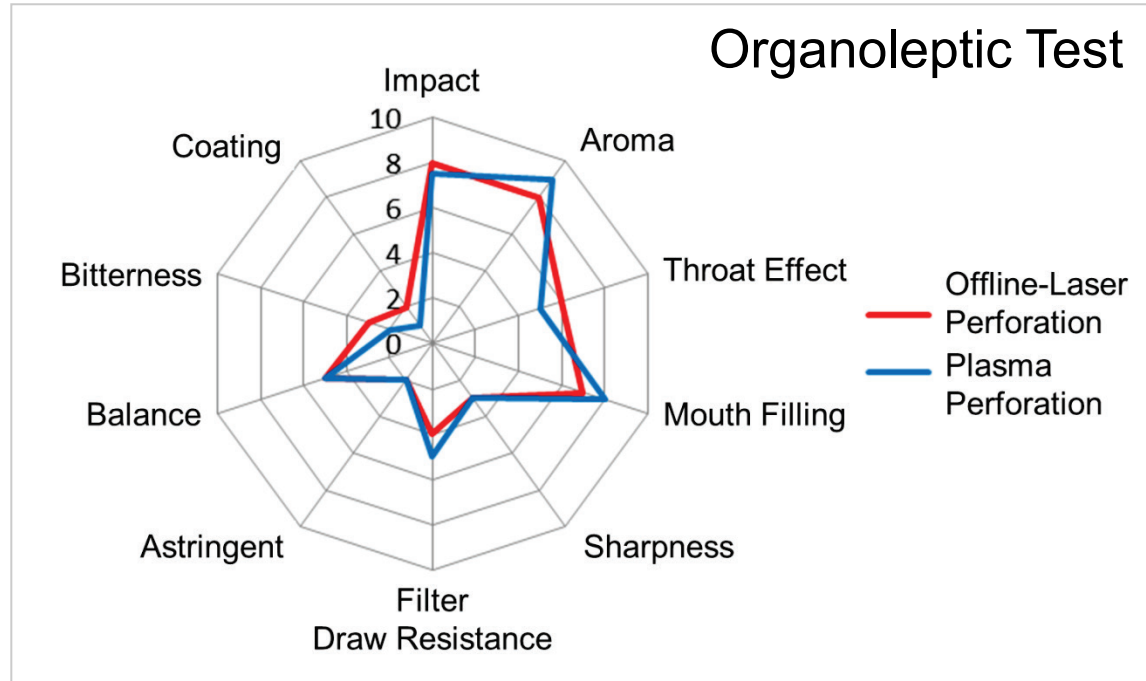


- Example 3 – Commercial test cigarettes produced by a Chinese manufacturer:
  - 280 CU offline LP: CO / tar = 1,04  
nicotine / tar = 0,105
  - 280 CU PP: CO / tar = 0,99 (-5%)  
nicotine / tar = 0,107 (+2%)
- Example 4 – Regular cigarette brand produced by a Chinese manufacturer:
  - Random smokers were provided with two cigarette samples (185 CU EP & 100 CU PP Tipping Paper)
  - Result: Smokers reported a much **smoother, softer and more natural taste** of the PP cigarettes

# SMOOTHER TASTE FOR “TSCHICK” (TSCHICKFABRIK GMBH, AUSTRIA)



1. Existing cigarette:  
Additive-free tobacco, 1500 CU offline LP
2. Same cigarette equipped with 800 CU PP



**Conclusion:** PP → intensified tobacco character, stronger aroma, more sweetness, very pleasant smoke impression



# PLASMA PERFORATION: SUMMARY

- Improved method for the generation of pre-perforated Tipping Paper
- Low-temperature dielectric barrier plasma discharges within an inert gas surrounding
- Micro-evaporation events either in bands or on the entire Tipping Paper surface
- Formation of tiny perforation holes with high hole density



# PLASMA PERFORATION: ADVANTAGES

- 1<sup>st</sup> benefit of PP: Highest stability of the air permeability and filter ventilation
- 2<sup>nd</sup> benefit of PP: Enhanced efficiency in ventilation rates and smoke yields reduction with focus on low CO values due to significant diffusion effects
- 3<sup>rd</sup> benefit of PP: Improvement of the sensory properties of cigarette smoke

PLASMA PERFORATION IS THE SMARTEST AND MOST RELIABLE WAY TO ACHIEVE SPECIFIC REGULATORY TARGETS

# THANK YOU FOR YOUR VALUABLE QUESTIONS & FEEDBACK!

