Non-Thermal Plasma-Assisted VOC Decomposition: Influence of Catalyst Type, Electron Energy, and Gas Residence Time

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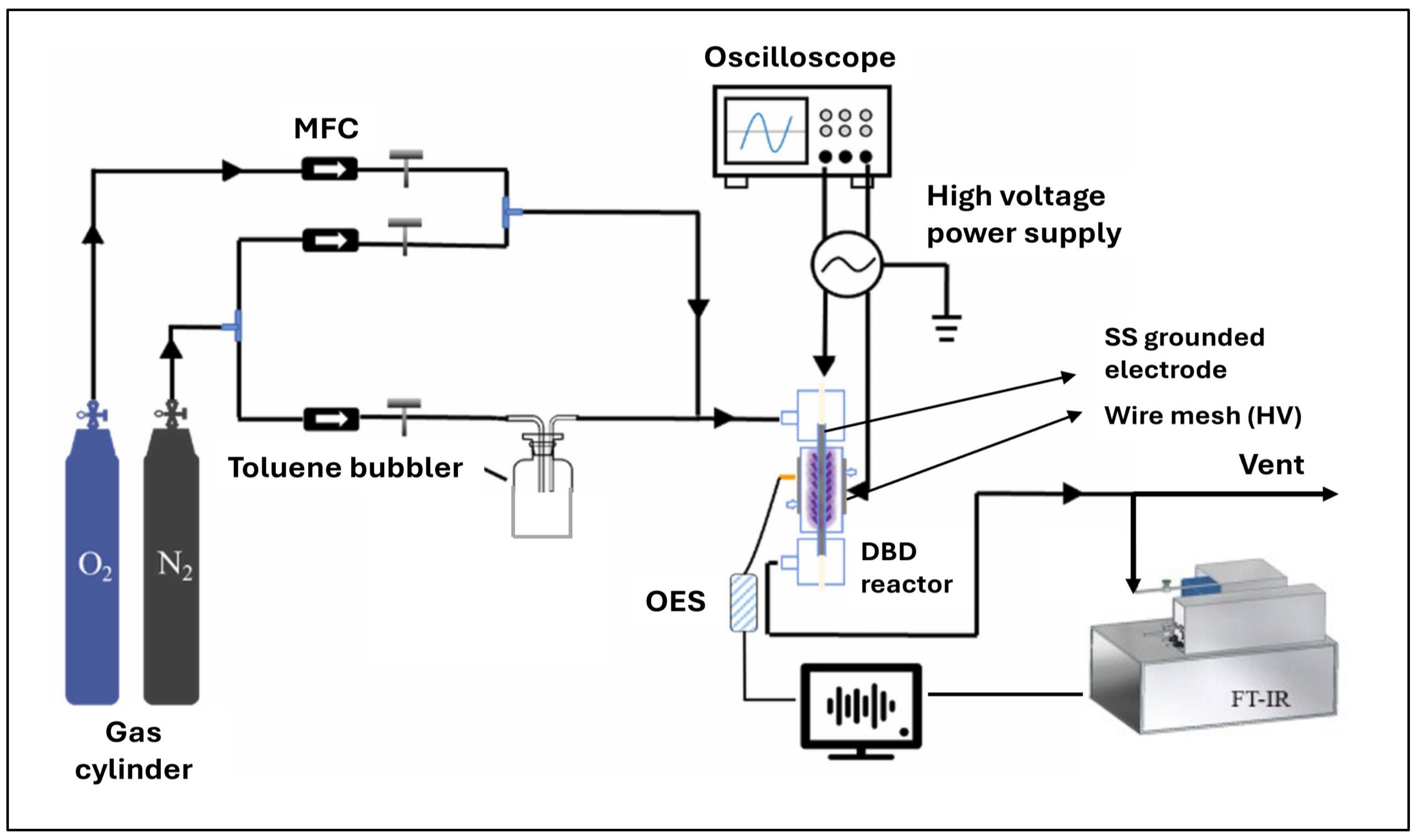
Introduction and Experimental Setup

- **Volatile organic compounds (VOCs)** emissions from industries, vehicles, and consumer products are a major source of **air pollution**, contributing to smog, organic aerosols, and **ozone (O_3) formation**. Many VOCs (e.g., benzene, toluene, and formaldehyde) are **toxic or carcinogenic**, so their abatement is critical to protect public health and the environment.
- **Non-thermal plasma** can generate highly **reactive species** (·OH, O·, O_3, NOx radicals) enabling VOC degradation at **ambient temperature and pressure**. This makes plasma particularly attractive for treating VOC emissions where conventional methods (thermal incineration, adsorption, and biofiltration) are inefficient.
- **Here**, we conducted experiments using **different plasma reactors filled with catalytic pellets** and investigated their influence on **VOC degradation**. The **reactive species** generated in each reactor configuration were analyzed, and the **toluene removal efficiency** was compared across different plasma–catalyst combinations.

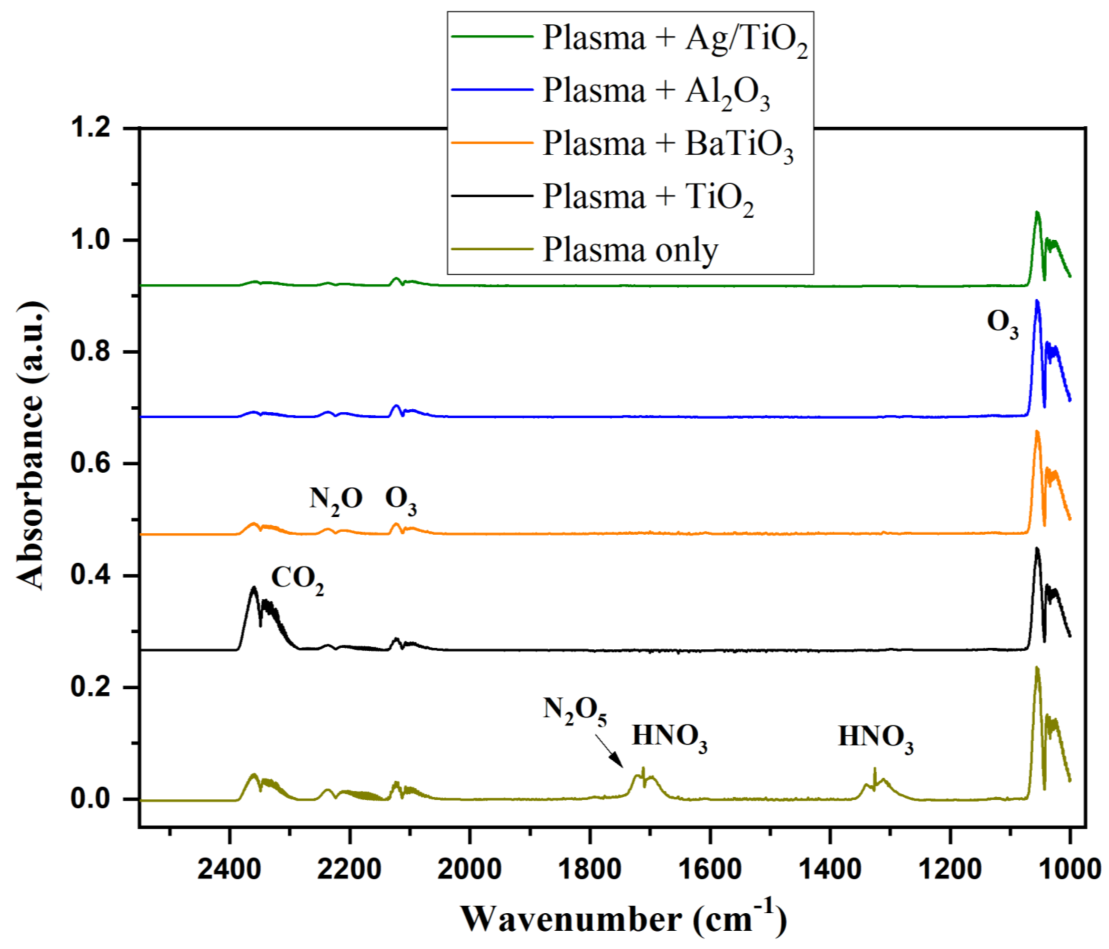


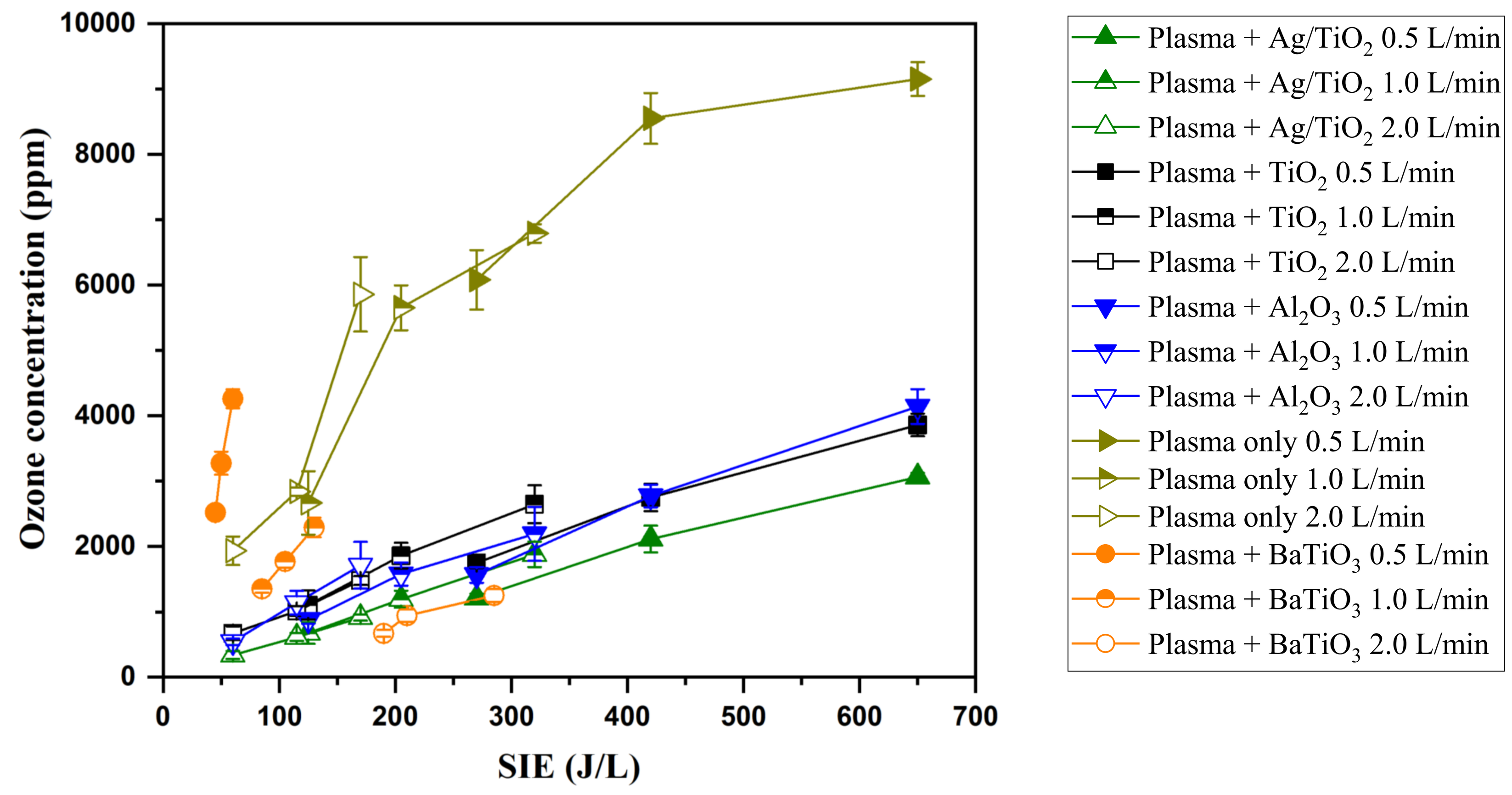
Plasma Reactor

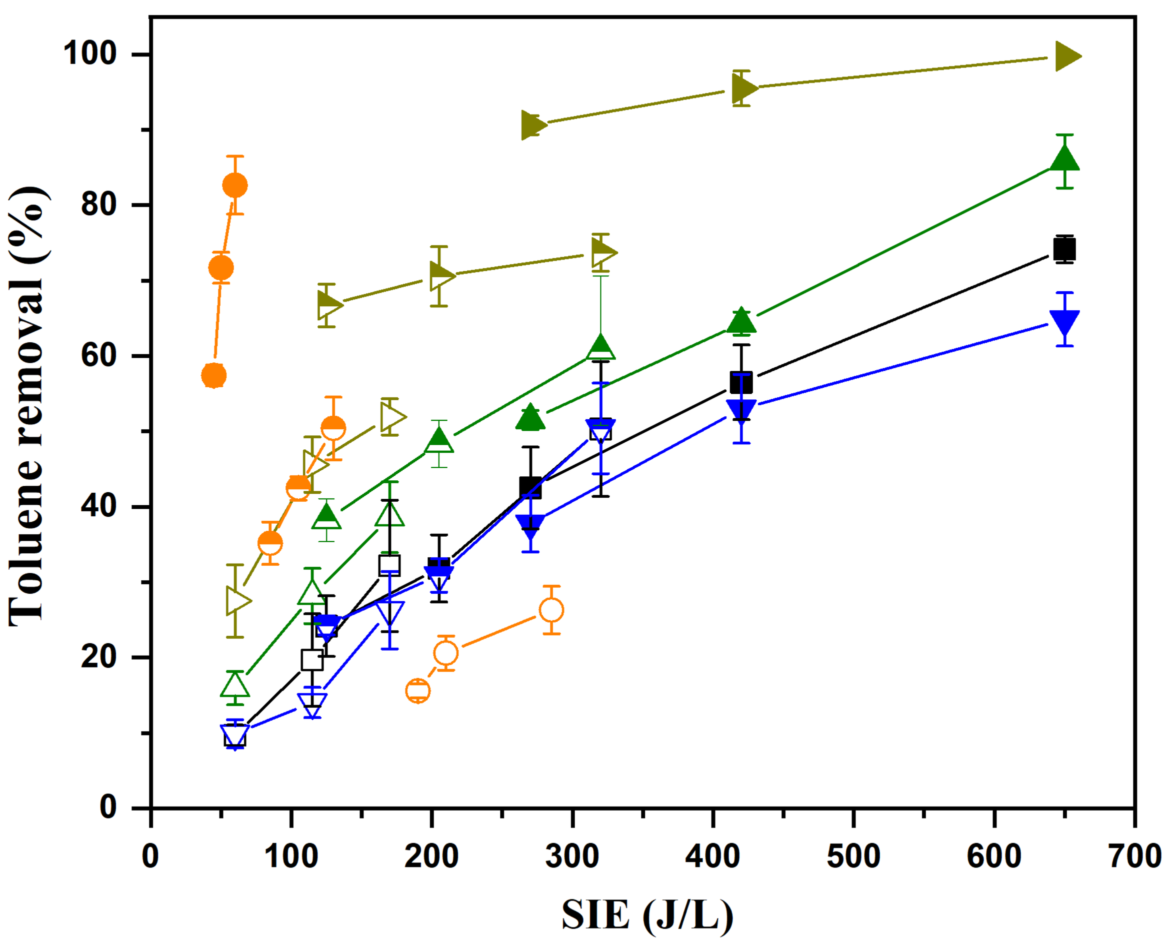
Plasma Reactor Characteristics and Toluene Degradation

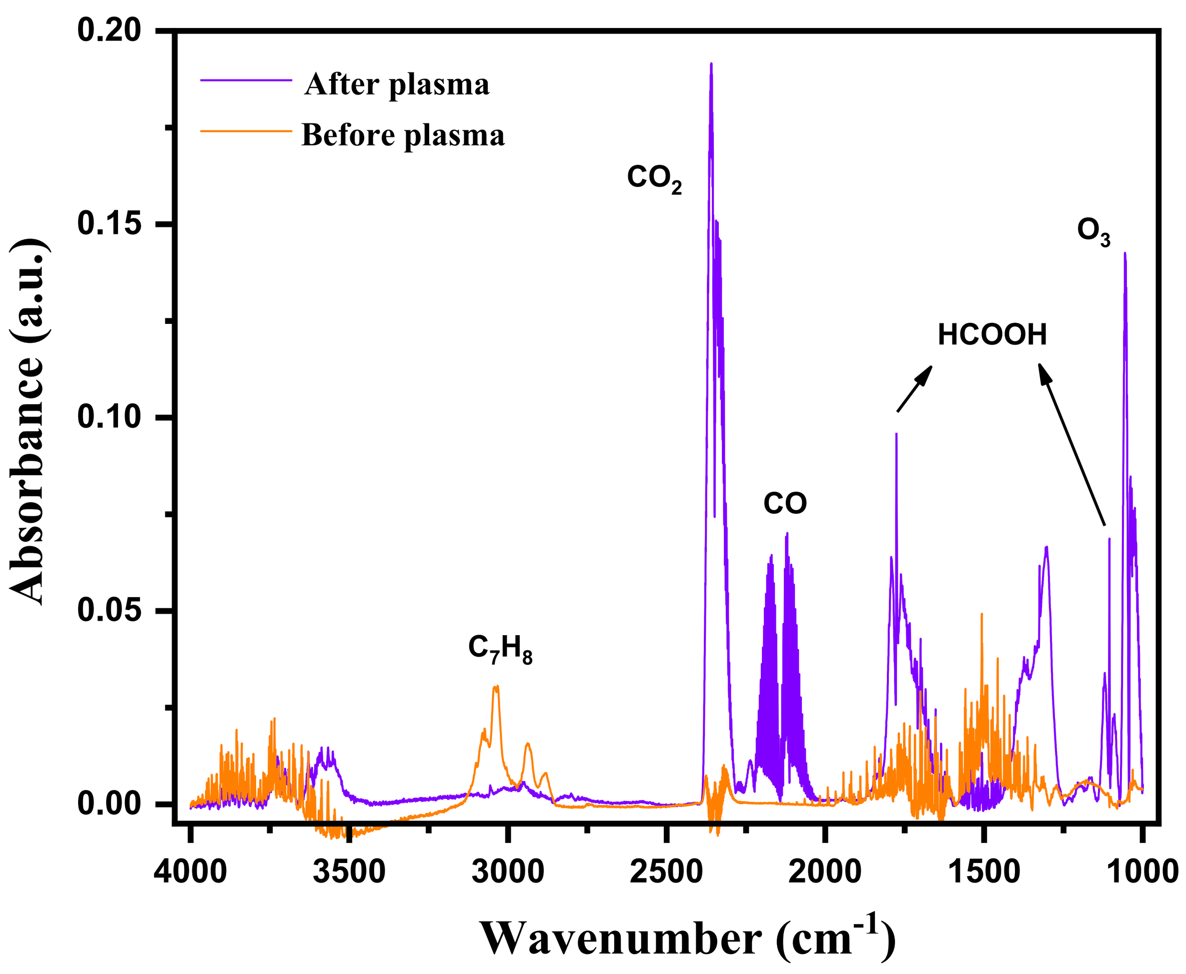
Experimental Conditions

- Discharge reactor length: 120 mm
- Discharge (gas) gap: 3.5 mm
- Catalytic materials (pellets): γ-Al_2O_3, TiO_2, $BaTiO_3$, Ag/TiO_2
- Carrier gas: N_2+O_2 (50:50)
- Gas flow rate: 0.5, 1.0, 2.0 L/min
- Applied voltage: 12 – 16.5 kV @ 1500
- Discharge power: 1 – 6 W









- **For catalytic pellets with higher dielectric constant**, a voltage drop across the dielectric is bigger than across the discharge gas gap. This reduces the discharge power delivered into the plasma, so the **SIE becomes lower.**
- The smaller voltage across discharge gas gap **weakens the electric field** in the plasma gap, reduces electron impact dissociation of O_2, and therefore **O_3 production decreases**.
- Catalyst-assisted plasma enhances toluene removal efficiency, especially **$BaTiO_3$ at lower SIE**, highlighting the role of catalysts in **improving VOC degradation**.
- The presence of CO_2, CO, HCOOH, and O_3 peaks after plasma treatment indicates **partial oxidation of toluene**, showing the need for optimized plasma–catalyst conditions.

✓ **Plasma alone** showed **higher energy efficiency at lower SIE**, but its efficiency decreased as SIE increased. In contrast, **TiO_2 and $BaTiO_3$ catalysts maintained more stable performance**, indicating their suitability for energy-efficient VOC abatement.

FAKULTA MATEMATIKY, FYZIKY A INFORMATIKY
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MATFYZ CONNECTIONS

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RECOVERY AND RESILIENCE PLAN