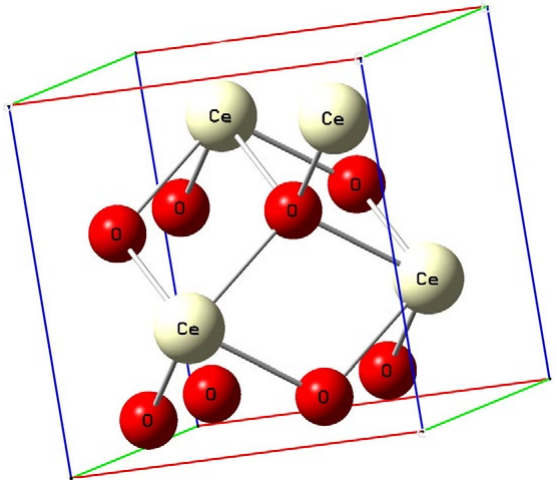
Ceria nanoparticles : synthesis and application for plasma catalysis

Presentation by Deepa Choudhry

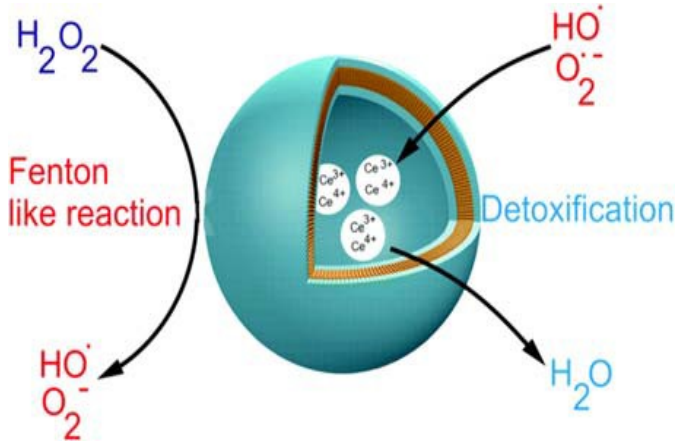
Ceria : Cerium oxide

Cerium(IV) oxide, is an oxide of the rare-earth metal cerium has a cubic fluorite structure.



Properties

- Chemical formula: CeO_2
- Basic oxide
- Single electron redox catalyst (Ce3+/Ce4+) ⟹ Oxidation of hydrocarbons
- such as toluene
- Excellent oxygen storage capability
- Enhanced redox reaction & trapping of reactive oxygen species



Environ. Sci.: Nano, 2015, 2, 33.
Spulber et al, Nanoscale, 2015, 7, 1411.

Project background

Importance of Ceria

- Catalytic activity of ceria is directly related to the number of oxygen vacancies in the crystal

- High Reducibility of Ce^{+4} state

Why Plasma catalysis?

Plasma catalysis allows thermodynamically difficult reactions to proceed at ambient pressure and temperature, due to activation of the gas molecules by energetic electrons created in the plasma. However, plasma is very reactive but not selective, and thus a catalyst is needed to improve the selectivity.

https://pubs.acs.org/doi/10.1021/acscatal.7b02733

- Role of oxygen vacancy on ceria surface?
- What are the reaction intermediates form (e.g., O•, CO, HOO•, HO•, CO_2, O_2 H•, CHO•, CH_3O•)?
- How Plasma coupled with ceria catalyst helps in methanol production?

$$CO_2 + 3H_2 \xrightarrow{\text{Ceria+ Plasma}} CH_3OH + H_2O$$

Objectives of the project

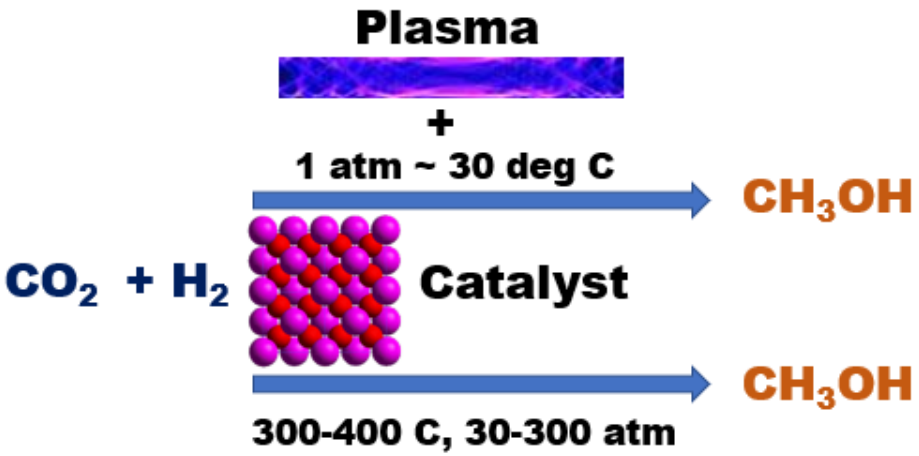
Objective 1 :

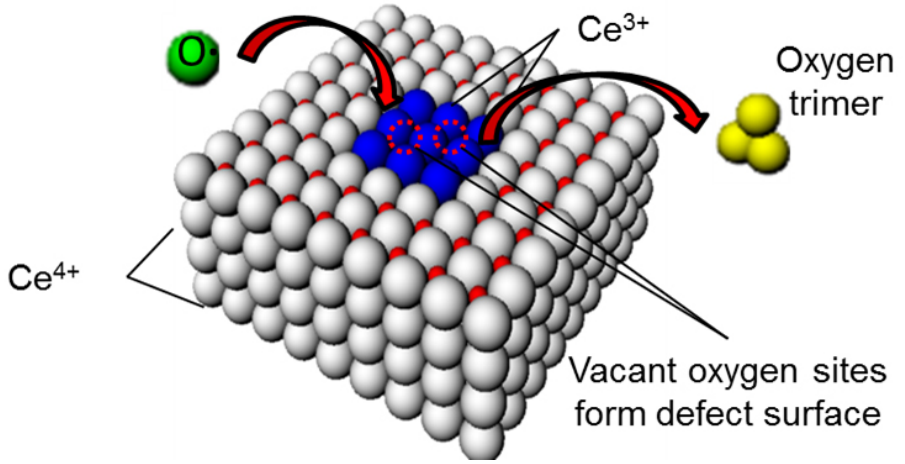
Synthesize ceria using acetate for higher yields via ozonation method.

Objective 2 :

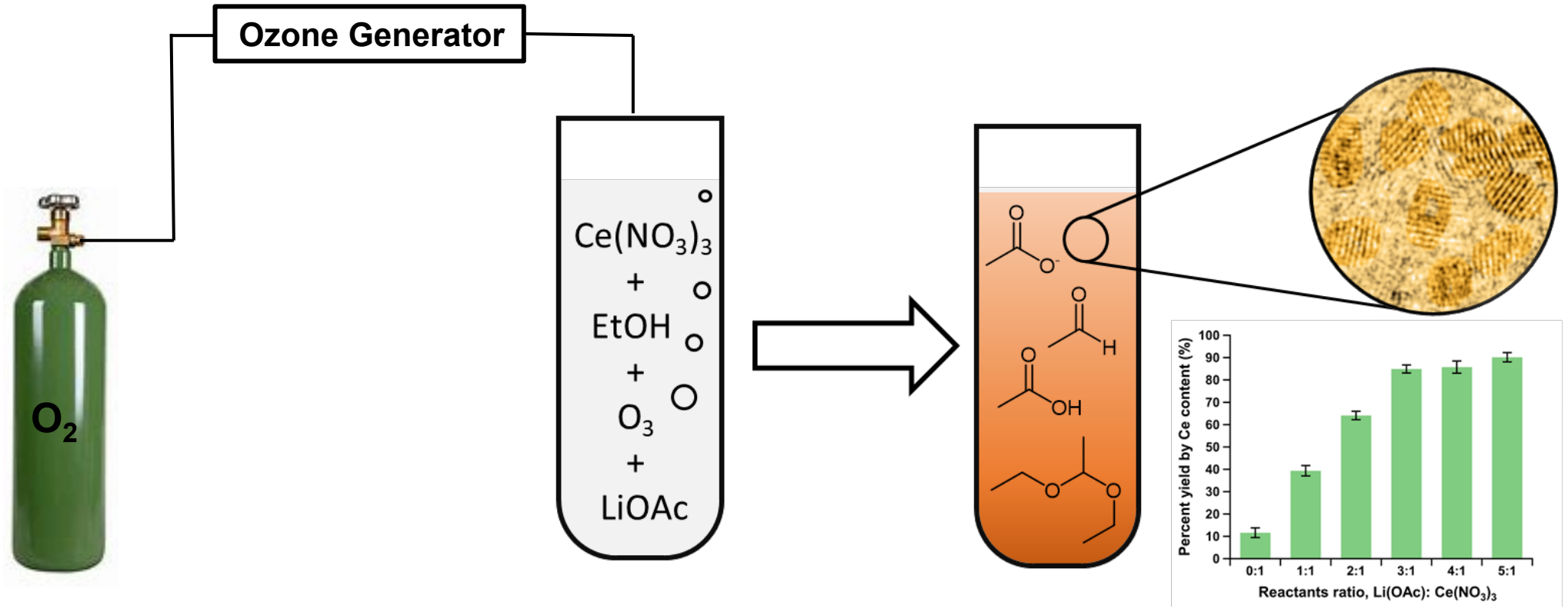
Investigate the effect of doped ceria on methanol production via hydrogenation of CO_2

catalytic plasma reactions and compare efficiency of reactor for differently doped ceria





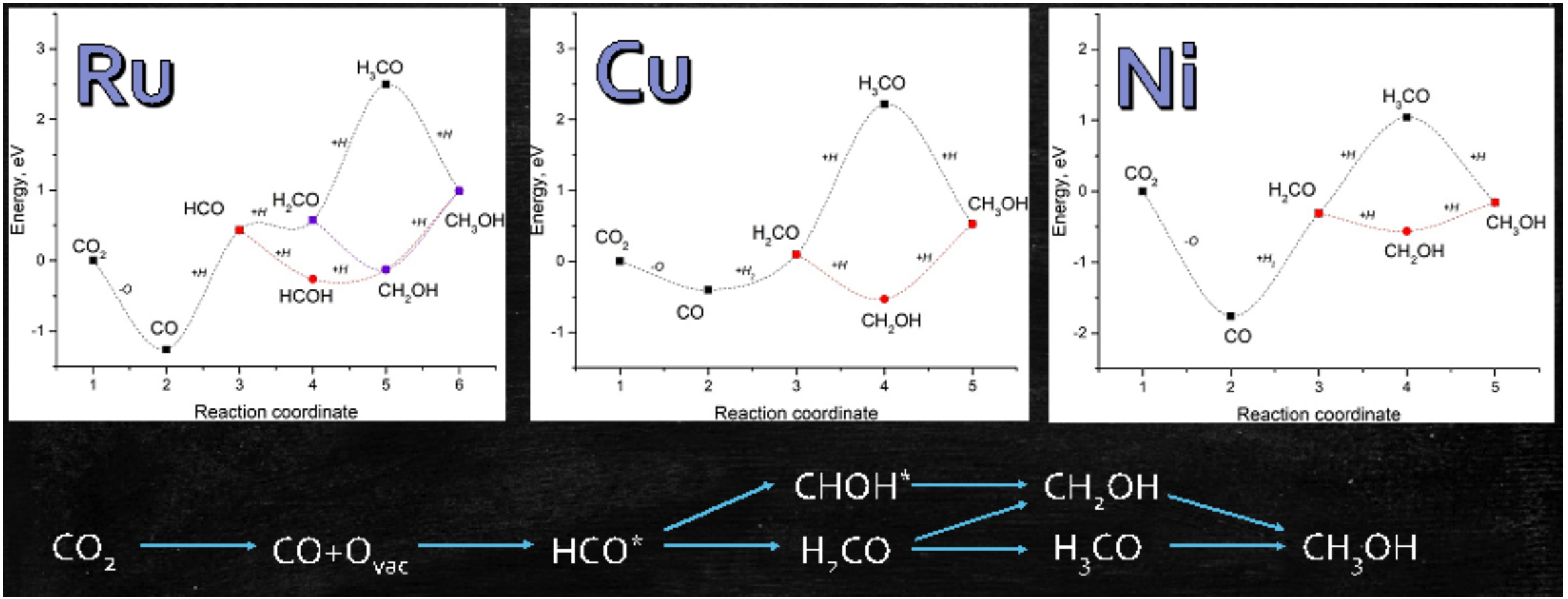
Experimental setup



$$Ce(NO3)_3.6H_2O + LiOAc.2H_2O + ETOH \xrightarrow{O_2/O_3} CeO_2 + CH_3CH(OET)_2 + H_2O$$

Why doped ceria?

Reaction pathways for $CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$ reaction at the M_4/CeO_2 interfaces



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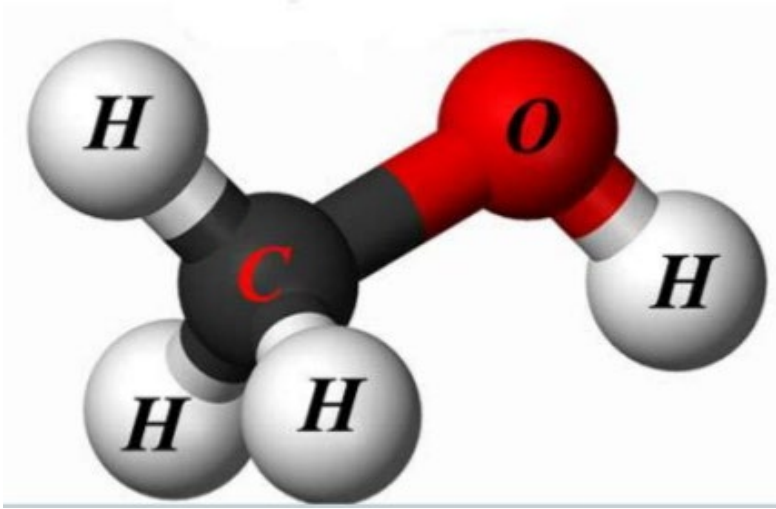
Investigate the effect of doped ceria on methanol production

Why methanol?

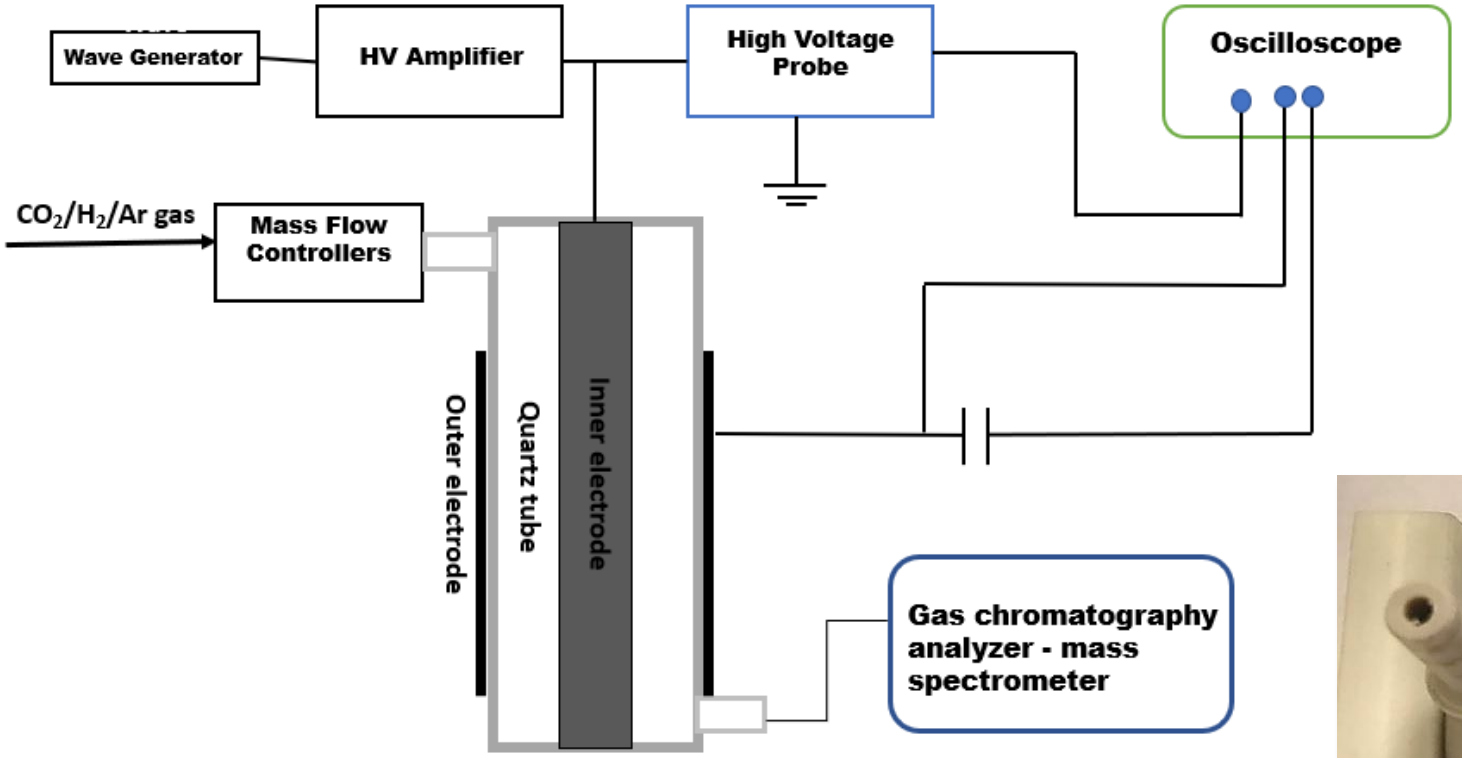
The chemical conversion and utilization of CO_2 is a promising step for the recycling of carbon resource.

Applications

- Liquid MEOH used as the fuel.
- Energy carrier
- Gasoline additive
- Methanol to hydrocarbons, olefins, gasoline
- Good for portable power



Experimental Setup for plasma catalysis



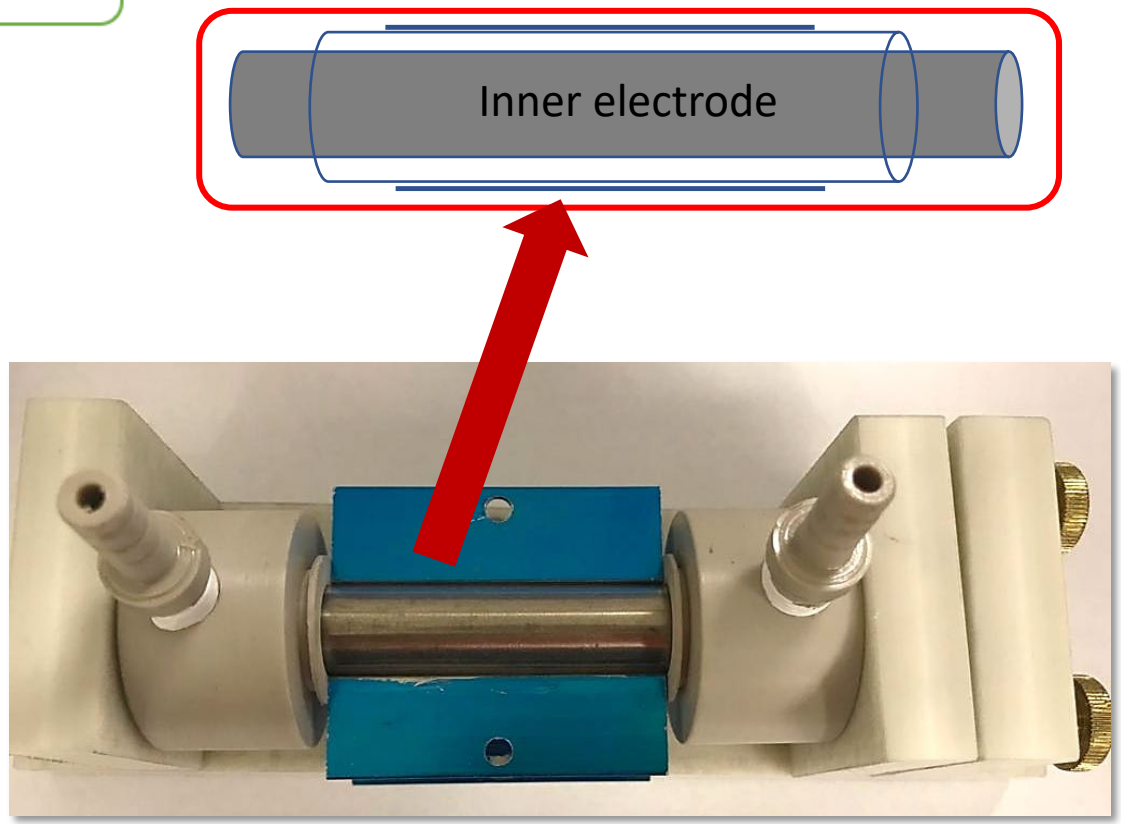


Fig: Plasma reactor

Conditions:

Chemicals:

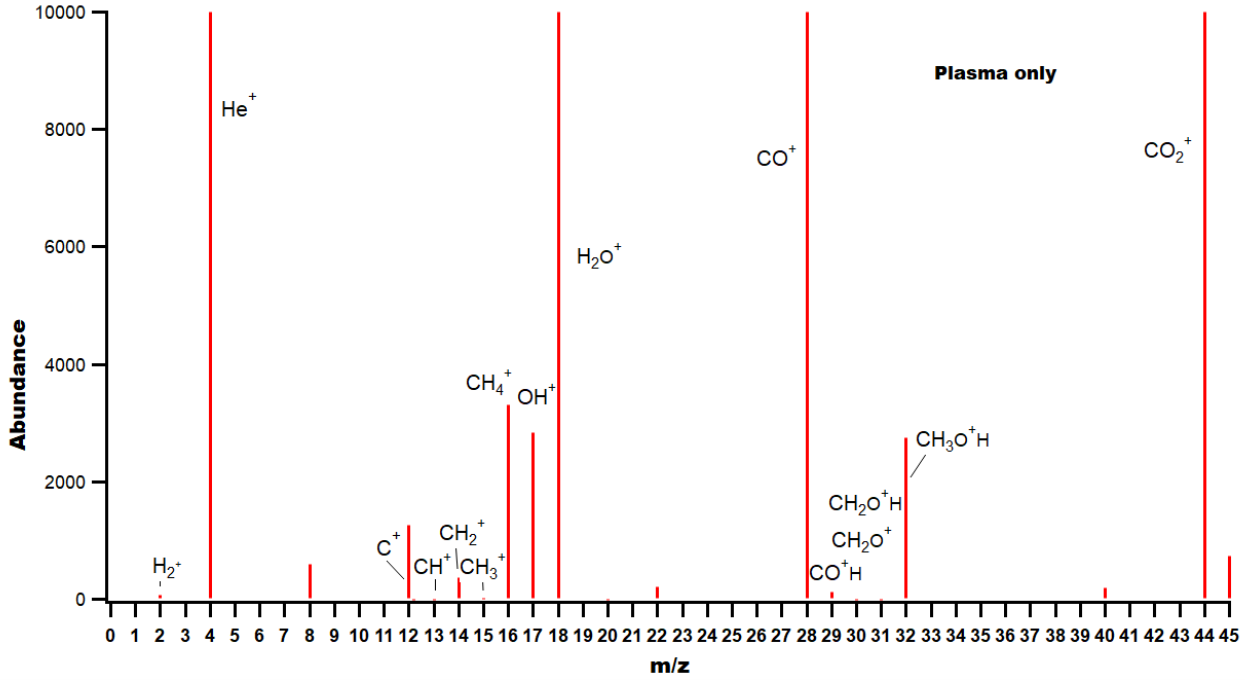
30 SCCM H_2; 10 SCCM CO_2

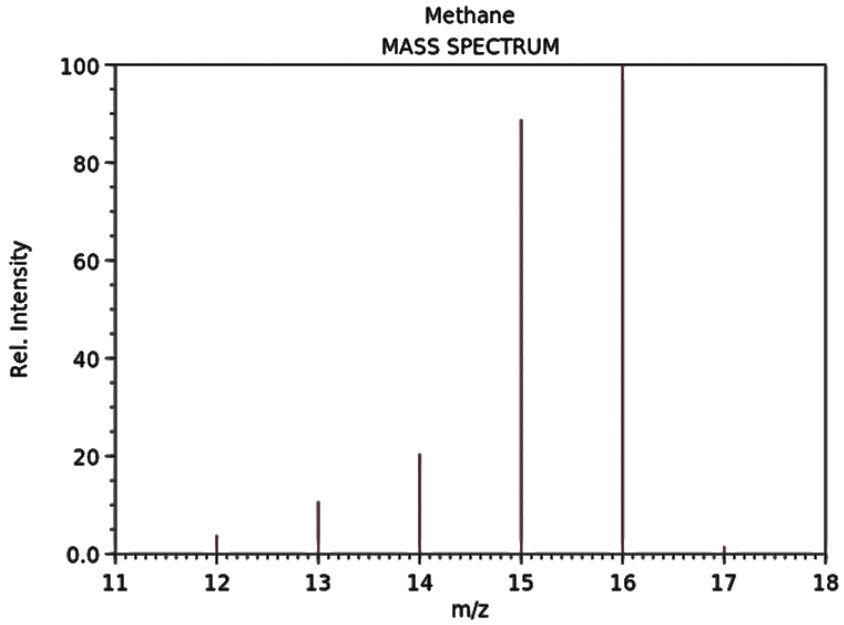
Plasma reactor:

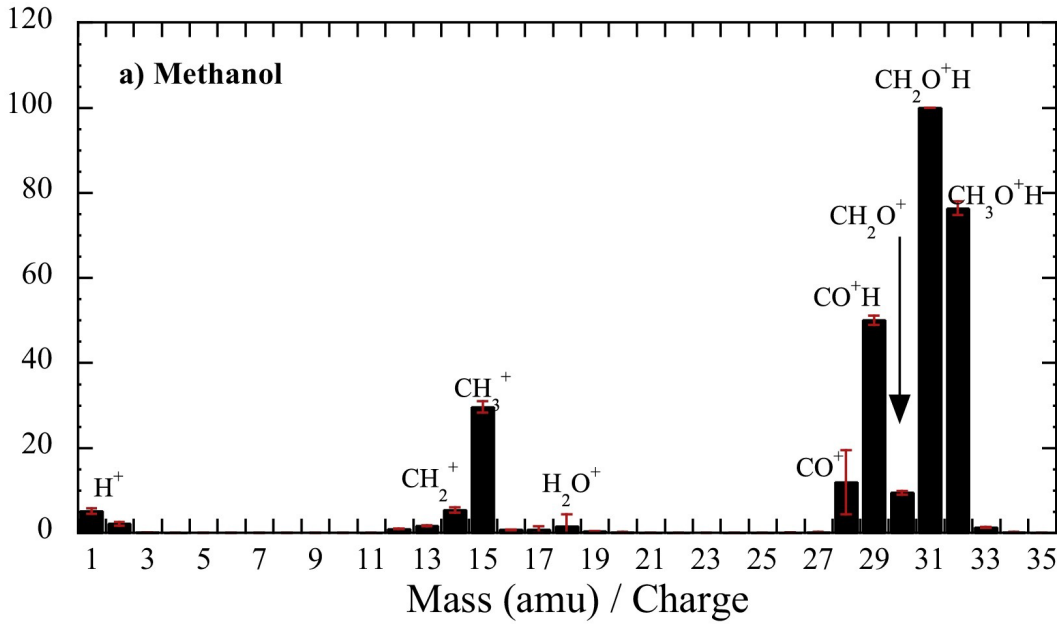
Applied voltage: 10 kV at 15 kHz

Detection : GC-MS

Set Temperature of coolant : -5 deg C







$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$

K.L. Nixon et al. / Intl. J. Mass Spec. 404 (2016) 48–59

Conclusion

- Cerium oxide nanoparticles have been successfully synthesized and characterized.
- The synthesis efficiency and crystallinity has increased by the additions of lithium acetate via ozone mediated routes close to 100%.
- Methanol can be produced via hydrogenation of CO_2 using plasma at atmospheric pressure and room temperature.

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