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Towards a Carbon Nanotube Ionization Source for Planetary Atmosphere Exploration

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Exosphere Ionization

Carbon Nanotubes as Cold Cathodes

Fig. 1 CNTEG:
- Electron field effect emission: generates current due to solid-state quantum tunneling.
- Moderate B field.
- Power-efficient, P < 0.1 Watts.
- Sufficiently powerful current (I ~ 800 µA/-0.1 µA).
- Very stable, dt/dI < 0.1 µA/s.
- Light-weight and robust.

Goal: To simulate & design ideal ionization volume demonstrating ion production via e impact.

- Box ~ 60 cm Beam width = cm - J = 100 µA/cm²

Europa’s Hydro-Exosphere

Overall water exosphere is uniform in 1 µm, H2O detection of excess H I/II may be an anomaly.

Sub-Jovian water is more than 10X dense at high altitudes.

Fig. 2 Side view of water θ = 30° & molecular oxygen θ = 90° simulation and observation,

Europa’s hill sphere extends to about 8 Rj beyond which Jovian gravity dominates.

Upper exospheric oxygen behavior is identical to other water-products: H2, OH, H2O.

Europa EGM

The Exospheric Global Model (EGM) is a 3D parallelized Monte Carlo code developed for the characterization of exospheres. Here, we model Europa. Test particles are ejected from Europa’s surface and travel up to ~ 15 Rj, following known energy distributions. The test particles are on ballistic trajectories and can escape, stick, and bounce on the surface. Furthermore the particles can be dissociated/ionized by physicochemical processes.

Results

Extended Exosphere Clouds are simulated, due to:
- Jovian gravitational drag is evident.
- Similar to sodium clouds at Io³.
- Escape rates could indicate an Enceladus-like hydrotorus.

Perspectives from Surface-Exosphere inhomogeneties:
- Sputtering may not be global².
- O⁺, S⁺ ions may not dominate.
- Water-product escape rates match previous studies.
- O₂ is thermalized to Tₑ, speeds are not sufficient to populate upper exosphere.

References

Carbon Nanotubes as Cold Cathodes

Fig. 3 SIMION simulation of CNTEG electrodes’ equipotentials and e trajectories. *Grids are at 50% transparency.

Fig. 4 CNTEG emission field emission measured at each electrode labeled above.

- CNTs are emitting consistently at ~ 60%.
- Anode emission is at 76%.
- Emission ~ 100µA is with a cathode gate distance of a = 250µm.

Day-night asymmetry is apparent. Effect is less for leading hemisphere as anti-jovian is close to anti-ploe.

Fig. 6 Top view of simulated atomic oxygen exosphere.

Fig. 8: SIMION simulation of CNTEG electrodes’ equipotentials and e trajectories. *Grids are at 50% transparency.

Fig. 7: SIMION simulation of CNTEG electrodes’ equipotentials and e trajectories. *Grids are at 50% transparency.

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