JPL SCIENCE HIGHLIGHT: Science Mission Directorate (SMD)

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JPL Science Highlight: Planetary Program Support

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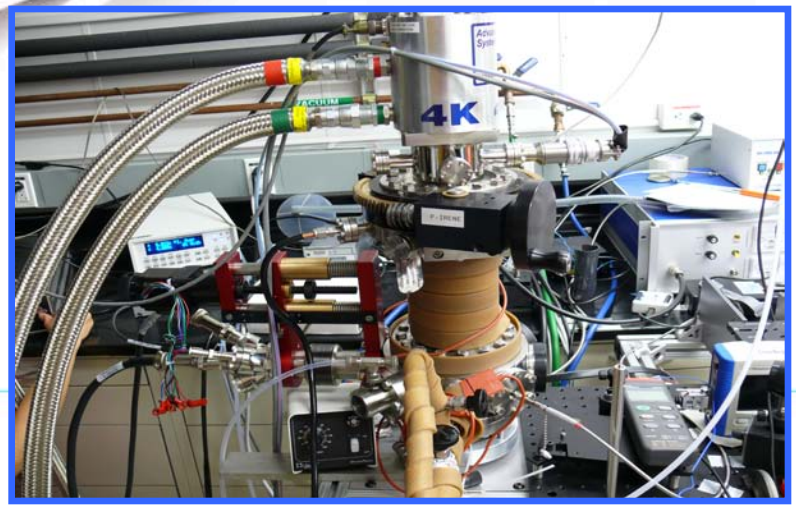
Laboratory & Modeling Studies to Quantify Electron Penetration into and Charging of Icy Surfaces of Moons of Giant Planets

Can Astrobiologically Important Organics Survive and Evolve in the Near-surface Ices Under an Extreme Radiation Environment?

Project Objective:

- To quantitatively determine penetration depths for electrons that cause radiation damage to organics in icy surfaces.
- To understand the phenomenon of ice-surface charging due to magnetospheric electron and ion bombardment of Jovian and Saturnian icy moons.
- Develop and assess spectroscopic identification methods for remote sensing organics on icy moons of giant planets

Laboratory & Modeling Studies to Quantify Electron Penetration into and Charging of Icy Surfaces of Moons of Giant Planets (Cont'd)



Electron Flux Comparison

At Europa = ~1.8 X 10^8 cm^{-2} s^{-1}
In the Lab = ~ 3 X 10^{13} cm^{-2} s^{-1}
The lab's low-energy (0.1 – 2 keV) electron flux is about 10^5 times higher than at Europa, but the primary electrons reaching Europa's surface have much higher energy (>100 keV – MeV). As a result, secondary electron flux within Europa's icy surface could be 100-1000 times higher than its primary electron flux. Hence, our lab simulations are comparable to processes on Europa's surface.

Potential future outer planet missions need a comprehensive understanding of radiation processing of icy surfaces in order to define instrument needs.

In order to better understand surface properties of icy bodies including Europa, Enceladus and Ganymede among others, scientists at JPL demonstrated the use of polycyclic aromatic hydrocarbons (PAHs) to study quantitative electron penetration into ice.

Studies presented here were conducted at JPL's "Ice Spectroscopy Lab (ISL)" of Dr. Murthy Gudipati, on ices kept at 30 K (on a 4 K cryogenic system). The electron gun is mounted on a translation stage (left), sample entry is towards the viewer, and on the right are the fiber optics for UV transmission (absorption) spectroscopy.

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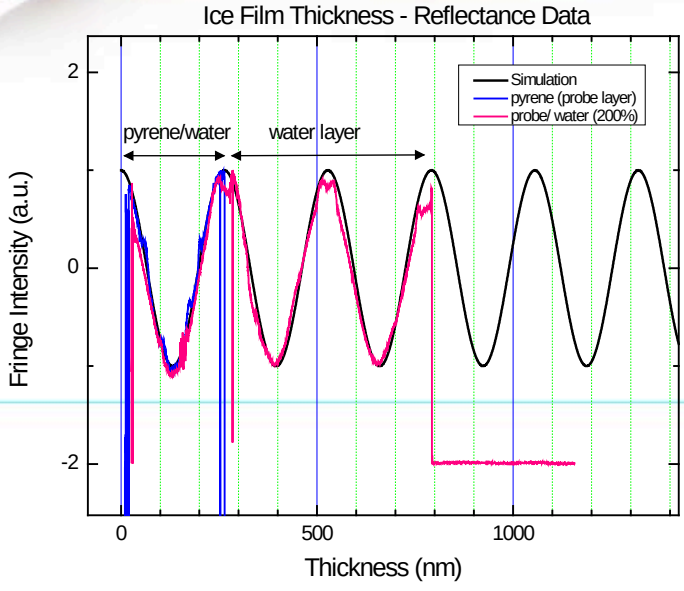
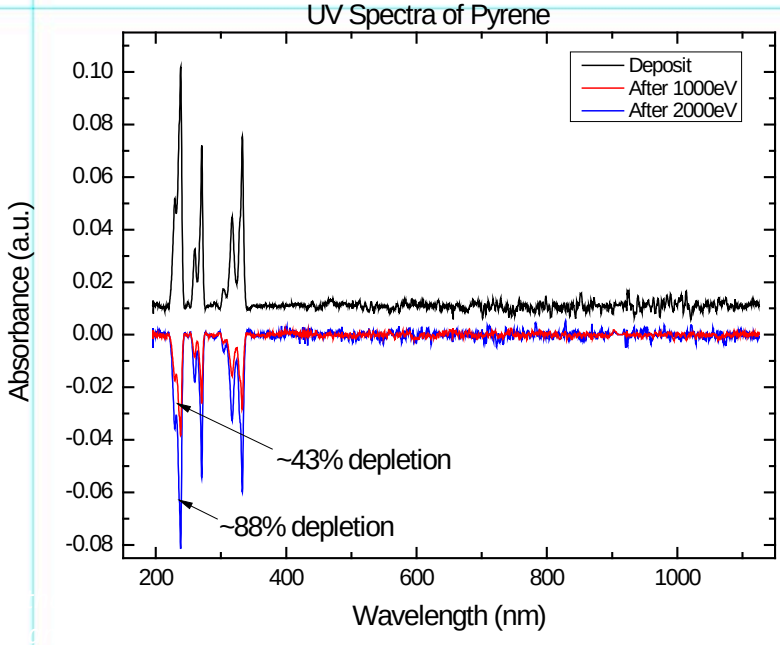


Using laser interference, thicknesses of PAH/ice are accurately determined.

UV-VIS spectra of pyrene/ice (depleted pyrene absorption is shown in negative absorbance units)



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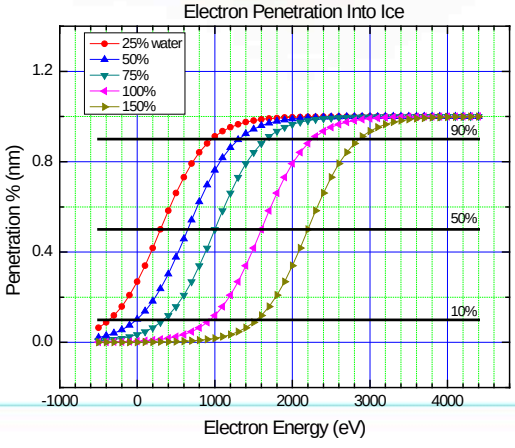
Results & Interpretation

Ice Film Thickness

	Deposit Time (min)	Total Thickness (nm)	Thickness of upper ice layer (nm)
WATER ICE	30	203	n/a
PYRENE/ICE	30	235	n/a
25% WATER	37.5	306	70
50%	45	330	120
75%	52.5	455	207
100%	60	484	240
150%	75	495	300
200%	90	737	485
500%	180	1236	1020

Penetration Depth at 50%

Water Ice Layer (nm)	Electron Energy (eV)
70 (25%)	300
120 (50%)	650
207 (75%)	1000
240 (100%)	1600
>300 (>150%)	2200



Modeling of Electron penetration through ice.

Conclusions:

- Low-energy electrons penetrate deeper than predicted by existing models.
- Even low-energy (100 eV – 2 keV) electrons could first ionize and then destroy organics within several hundred nanometers to few microns of the ice surface.
- Chemical processes observed here are comparable with the chemistry that could occur due to the secondary electrons generated in the ice by the high energy electrons (keV - MeV) bombarding Europa.
- Trapped excess surface electrons could repel incoming magnetosphere electrons and need to be further studied.

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Implications

So far there have not been direct quantitative electron penetration measurements (energy vs. depth) on ices. All the models use data derived from other targets such as silicon. Our experiments show that electrons penetrate deeper than predicted by existing models. The scientists plan to extend these experiments to higher electron energy region and compare with the existing models. Organics in ices are easily destroyed even with low-energy electrons, implying that it may be difficult to detect organics on highly irradiated surfaces and subsurface probing may be inevitable.

Significance to Solar System Exploration

The proposed Europa Jupiter System Mission (EJSM), with its focus on Europa and Ganymede, need the understanding of radiation processing of icy surfaces in order to define instrument needs. This research not only strongly helps these goals, but also in the data analysis of present and future flagship missions to icy bodies.