Why is Europa Dark in the Far-Ultraviolet? Insights from the Laboratory. B. D. Mamo[1,2,3], J. S. Brody[2,3], B. D. Teolis[2,3,1], K. D. Retherford[2,3,1], T. M. Becker[3,1], P. M. Molyneux[3], U. Raut[2,3,1], [1]University of Texas at San Antonio, San Antonio, TX, [2]Center for Laboratory Astrophysics and Space Science Experiments (CLASSE), Southwest Research Institute, San Antonio, TX, [3]Southwest Research Institute, San Antonio, TX (bereket.mamo@contractor.swri.org)

Introduction: Decades of infrared observations have established water ice as the dominant component of Europa's surface [1, 2, 3]. The leading hemisphere, in particular, has the most pure ice [4], with well-defined, strong absorption features that agree well with laboratory spectra [2] and abundances that reach >80 wt.% in select bright regions [5].

In addition to its absorption features in the infrared, water ice presents a distinct signature at ultraviolet wavelengths. Laboratory studies show water ice has a sharp absorption edge at ~165 nm—its reflectance remains dark at shorter wavelengths but exhibits a sharp rise longward of the absorption edge. This feature has been detected in icy Solar System bodies, including the rings and icy moons of Saturn [6, 7, 8]. Given the large surficial abundance of water ice on Europa, we expect to see this absorption edge in far-ultraviolet (FUV) reflectance spectra of its surface. Hubble Space Telescope (HST) observations, however, indicate this feature is missing in its FUV spectrum [9, 10], with the reflectance instead showing only a gradual increase with increasing wavelength through the mid-UV (Figure 1). The absorption edge is also missing in the icy Jovian satellites Ganymede [11] and Callisto [10].

Europa is set to be explored by the upcoming Europa Clipper mission as well as ESA's Jupiter Icy Moons Explorer (JUICE) mission. Yet, our understanding of the surface spectroscopic behavior, particularly in the FUV, remains limited due to the lack of relevant laboratory measurements. We address this knowledge gap by performing laboratory studies that investigate the roles of electron irradiation and other non-ice inclusions in suppressing the water ice absorption edge. Specifically, we irradiate pure H_2O ice films and H_2O films containing small concentrations of CO_2 with 5 keV electrons and measure changes in the FUV to mid-IR (115 nm–16 µm) reflectance.

Experimental Setup: Electron irradiation experiments are performed using the 'Mordor' chamber at the Center for Laboratory Astrophysics and Space Science Experiments (CLASSE) at Southwest Research Institute. This ultra-high vacuum chamber (base pressure of ~10^{-10} Torr) supports a 4 K He cryostat that is mounted vertically on a rotatable stage. A 6 MHz, gold-coated quartz crystal microbalance (QCM) is embedded into a copper block that sits at the terminal end of the cryostat. Pure and mixed water ice films are deposited onto the QCM using micro-capillary dosers that exude a collimated flux of gas towards the cooled QCM. The microbalance reports the areal mass (ng/cm^2) of the condensed films and has a sensitivity of 0.04 monolayers (ML) for water ice. The gold-coating on the front face of the QCM also allows for specular reflectance measurements of films whose column densities are well-constrained.

Deposited films are irradiated using a Kimball Physics electron gun (EGG-3101C) in a step-wise manner to a target fluence. Between each irradiation step, reflectance spectra are obtained using a suite of spectrometers. FUV spectra (115–200 nm; Figure 1) is measured using a dispersive monochromator (McPherson 234-302) and a Photonis channeltron detector (Model # 5901) coupled to an MDHL (microwave-discharge hydrogen flow lamp) light source [12]. Formation of radiolytic products in the ice are detected by tracking changes in the infrared spectrum (1.1–16 µm), which is obtained using a Thermo-Nicolet is50 Fourier transform infrared

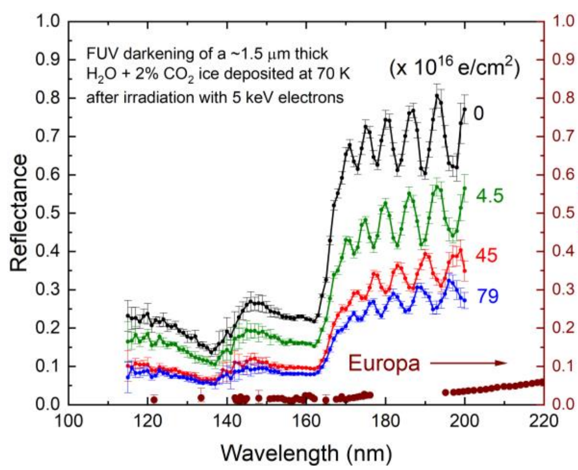

Figure 1: FUV reflectance darkening of a ~1.5 µm thick H_2O film containing 2% (by number) CO_2 following irradiation with 5 keV electrons to increasing fluences (given by the numbers adjacent to the curves in units of 10^{16} e/cm^2). The spectrum was obtained using a dispersive monochromator after deposition of the ice film at 70 K. The fringes >170 nm are known artifacts caused by thin film interference effects. Radiolytic processing of Europa's ice (containing impurities like CO_2) by magnetospheric electrons could contribute to Europa's dark ultraviolet albedo [9].

spectrometer. Spectral coverage of the aforementioned spectrometers is bridged by an Ocean Optics Maya Pro spectrometer (190–1100 nm).

Results from our electron irradiation experiments of pure and mixed H_2O ice films will be presented and candidate FUV-darkening radiolytic product(s) identified to explain the missing ~165 nm absorption edge in the spectra of Europa and other icy Jovian satellites.

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