

**EUROPA'S POROUS ICE RHEOLOGY AND IMPLICATIONS FOR ICE-PENETRATING RADAR SCATTERING LOSS.** Sunwoong Lee, *Massachusetts Institute of Technology, Cambridge, MA 02139, USA*, Robert T. Pappalardo, *University of Colorado, Boulder, CO 80309-0392, USA*, Nicholas C. Makris, *Massachusetts Institute of Technology, Cambridge, MA 02139, USA*, (makris@mit.edu).

It has been proposed that Europa's potential subsurface ocean could be detected by ice-penetrating radar (Chyba *et al.* 1998; Moore 2000). The main challenge to radar sounding on Europa lies in accrued absorption due to warm or dirty ice (Chyba *et al.* 1998; Moore 2000), and scattering due to ice surface roughness and volume inhomogeneities (Greeley *et al.* 2004). Both Earth-based radar-wave backscattering data (Black *et al.* 2001) and extremely low cycloidal crack initiation strength (Hoppa *et al.* 1999) show that the ice shell may be highly porous. Furthermore, high resolution surface images from the Galileo mission shows that it may also be highly fractured. These inhomogeneities together with surface roughness will lead to scattering losses, the significance of which need to be assessed.

We show that the size of vacuous pores or brine pockets in Europa's ice shell are likely very small compared to ice-penetrating radar wavelength, based on the data by Black *et al.* (2001) and terrestrial ice rheology model for fracture strength (Weeks and Ackley 1982). This has the significant implication that porosity-induced scattering should not be significant. This substantially differs from what has been predicted by Eluszkiewicz (2004), who arbitrarily assumed meter-scale spherical pores. We show that this overestimation of pore size leads to a corresponding overestimation of transmission loss due to scattering by orders of magnitude.

Fractures should only cause noticeable scattering if (1) the surface normal of the fault exceeds the critical angle, typically 32-degrees for electro-magnetic waves incident from ice to vacuum, and (2) fracture opening widths are at least wavelength scale, on the order of a meter, to negate any significant tunneling of evanescent waves. It is not yet clear what mechanisms could be responsible for such large scale opening widths, based on our current understanding of tidally driven fractures on Europa (Nur 1982; Lee *et al.* 2003). Ice-penetrating radar waves will also be significantly occluded by Europa's rough outer ice-vacuum boundaries when the surface is inclined so that the angle between the local vertically-directed incident wave and surface normal is greater than the critical angle. Based on Europa's surface topography (Prockter *et al.* 2002; Figueredo *et al.* 2002; Nimmo *et al.* 2003), we show that rough surface scattering by Europa's ice surface would not be a significant radar design impediment.

Consequently, there seems to be no compelling reason at the present time to expect large scattering loss for the roughly 3-m wavelength orbital ice-penetrating radar missions planned for the Jupiter Icy Moons Orbiter. It is not yet clear whether any scattering mechanisms exist to significantly limit radar penetration of Europa's ice shell compared to high absorption

loss by warm or dirty ice.

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