Experimental relationship between dielectric properties and ilmenite content with the effect of porosity for the understanding of Moon's subsurface structure

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Mare basalt stratigraphy on the Moon helps to advance our understandings of a lunar volcanic evolution and the thermal history of the Moon. Lunar Radar Sounder (LRS) onboard Kaguya spacecraft employed 5 MHz electromagnetic wave to receive a backscattering wave from both the lunar surface and buried layers at depths of a few hundreds of meters within major lunar maria. Kaguya LRS study found a heterogeneous distribution of horizontal subsurface features, which correlates negatively with high concentration of ilmenite ($FeTiO_3$) as a strong absorber for low frequency electromagnetic waves. Although bulk rock density (or equivalently porosity) and chemical composition are critically important parameters in predicting the subsurface layering, their quantitative relations with dialectic properties are not clear for Apollo returned lunar samples with variable porosities and variable compositions. Previous experimental studies suggested that the real part of the dielectric properties is constant and independent of TiO_2 content when normalized to a constant porosity, suggesting less absorption. However, this studies contradicts the LRS observation with a strong absorption. In this presentation, we show the effect of ilmenite content on complex dielectric properties (dielectric constant and loss tangent) with the effect of porosity, using lunar analog samples as a mixture of ilmenite and cement. Measurements of dielectric properties of the analog samples at 5 MHz demonstrated that both dielectric constant and loss tangent have power-law dependences with the content of ilmenite. The power-law relations between ilmenite contents and complex dielectric constant for analog samples were derived in a range of ilmenite content up to 30 wt% by a least square regression. In addition, by considering a mixture of the poreless lunar analog samples and air, I derived a new experimental relationship between dielectric properties and ilmenite content with the effect of porosity by Lichtenecker's mixture formula. The power-law dependence of complex dielectric constant with the content of ilmenite gives a quantitative estimation of lunar dielectric constant through a radar sounding, and explains why LRS could detect subsurface layers beneath high concentration area of ilmentite in lunar maria.

