Introduction: Studies of lunar soils showed that space weathering of silicates results in reduction of iron and formation of metallic iron grains ranging from nano- \((\text{nFe}^0)\) to submicron and micron \((\mu \text{Fe}^0)\) scale [1]. In immature soils, nFe\(^0\) is dispersed in the 100-200 nm-thick rims of soil particles, typical diameter of nFe\(^0\)-grains being 3nm [2]. Mature soils contain both nFe\(^0\) and \(\mu \text{Fe}^0\) all over the particle volumes, \(\text{Fe}^0\) in agglutinitic glasses averaging up to 0.17\(\mu\text{m}\) in diameter [3].

\(\mu \text{Fe}^0\) forms in so called ripening process, when the larger grains grow at the expense of the smaller ones. The process occurs at high temperatures, most quickly in impact melt. Lunar soil particles with embedded \(\mu \text{Fe}^0\) were melted for short times and still contain much nFe\(^0\) that is an effective light absorber. This makes lunar soil particles with \(\mu \text{Fe}^0\) too dark to enable \(\mu \text{Fe}^0\) to control the optical properties of the Moon. On Mercury, more intensive meteoritic bombardment may convert nFe\(^0\) to \(\mu \text{Fe}^0\) more efficiently, enabling \(\mu \text{Fe}^0\) to become significant for optical properties of the surface.

Spectral effects of growth of \(\text{Fe}^0\)-grains embedded into transparent powders were studied experimentally in [4]. Laboratory measurements show variations in reflectance and spectral shapes as a function of size. However, the size distributions are difficult to control and they are likely to be bimodal. Large \(\text{Fe}^0\)-grains formed mostly at the surfaces of pores that are paths of enhanced diffusion. Thus the experiments give mostly qualitative information.

In the present study, spectral effects of \(\text{Fe}^0\)-grains in size range from nm to \(\mu\text{m}\) are simulated with Mie theory and modified version of the model of spectral albedo for regolith-like surfaces [5].

Calculation of optical spectra of powders with embedded \(\text{Fe}^0\)-grains: \(\text{Fe}^0\)-grains in regolith particles are known to be spherical. Absorption and scattering coefficients of particles with such grains can be calculated with Mie theory provided that complex refractive indices \(n\) of \(\text{Fe}^0\)-grains are known. To avoid resonance effects, size distribution of ripening grains [6] was taken into account.

The spectral model [5] was modified to take internal scatterers into account. Since the absorption coefficients \(\alpha\) of regolith particles are proportional to volume fraction \(c\) of the embedded \(\text{Fe}^0\)-grains, the optical density of the soil particles \(\tau = c \alpha \propto lc\), \(l\) being particle size, so reflectance \(R\) of a soil and the shape of spectral curves are controlled by the value of \(lc\).

Fig.1 shows calculated optical characteristics of regolith particles with embedded \(\text{Fe}^0\) as functions of grain diameter \(d\) at different wavelengths \(\lambda\). At a given \(\lambda\), \(\alpha\) first grows with \(d\), then decreases (Fig.1a), because large grains \((d >> \lambda/4\pi n)\) are opaque and strong light absorption changes to light scattering (Fig.1b). Such behavior was qualitatively described in [7] and called “overmaturation”. The maxima on \(\alpha(d)\) curves correspond to minima on \(R(d)\) curves (Fig.1c,d) that shift to larger \(d\) at longer \(\lambda\).

Fig.2 shows calculated reflectance spectra of bright material with embedded \(\text{Fe}^0\)-grains of different sizes \(d\) for all range of \(lc\) typical of lunar soils. The change of spectral shapes with grain size is the same as observed in experiments [4] (here UV range 0.2-0.3\(\mu\text{m}\) is added). Calculations enable us to determine more exactly the critical sizes \(d^*\) of \(\text{Fe}^0\)-grains above which regolith becomes brighter compared to that with nFe\(^0\)-grains. For typical \(l\) and \(c\), \(d^* = 30, 40, 100, 250,\) and 750\(\mu\text{m}\) at \(\lambda = 0.2, 0.3, 0.5, 1\) and 2\(\mu\text{m}\), respectively.
In Fig. 3 the effect of addition of Fe$^0$ of various sizes for Fe$^{2+}$-bearing lunar-like material is presented. As shown, the growth of nFe$^0$ to 0.1µm crucially changes the spectra in the visible range; and >1µm grains do not essentially affect the spectra in 0.3-2µm range.

**Implication to spectral variations on Mercury:** We modeled spectral variations on Mercury in the same way as those for particle size fractions of lunar soils [5]. Spectrum of mature soil is calculated from that of immature one by decreasing particle size and adding Fe$^0$-grains (Fig.4). For lunar spectra, this is possible by immature one by decreasing particle size and adding Fe$^0$-grains only [5]. To reproduce the spectra [10] of dark areas on Mercury starting from those of overlaying crater rays, presence of µFe$^0$ is required.

**Conclusions:** Modification of the model of spectral albedo [5] and Mie theory enabled us:

1. to determine “overmaturation” sizes of Fe$^0$-grains embedded into regolith for different wavelengths,
2. to estimate µFe$^0$/nFe$^0$ ratio from the optical spectra of particulate surface,
3. to find evidence for the spectral dominance of µFe$^0$ over nFe$^0$ on Mercury.

**Acknowledgment:** We thank M. A. Kreslavsky and L. V. Moroz for discussions. This study was supported by CRDF grant UKP2-2897-KK-07.

**References:**