Low-temperature Optical Properties of Interstellar and Circumstellar Icy Silicate Grain Analogues in the Mid-infrared Spectral Region

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Abstract
Two different silicate/water ice mixtures representing laboratory analogs of interstellar and circumstellar icy grains were produced in the laboratory. For the first time, optical constants, the real and imaginary parts of the complex refractive index, of such silicate/water ice mixtures were experimentally determined in the mid-infrared (IR) spectral region at low temperatures. In addition, optical constants of pure water ice and pure silicates were derived in the laboratory. Two sets of constants were compared, namely, “measured” constants calculated from the transmission spectra of silicate/ice samples, and “effective” constants calculated from the optical constants of pure silicates and pure water ice samples using different mixing rules (effective medium approaches). Differences between measured and effective constants show that a mixing (averaging) of the optical constants of water ice and silicates for the determination of the optical properties of silicate/ice mixtures can lead to incorrect results. Also, it is shown that a part of the water ice molecules is trapped in/on silicate grains and does not desorb up to 200 K. Our unique data are well-timed with respect to the new and challenging space mission, James Webb Space Telescope (JWST), which will be able to provide novel and detailed information on interstellar and circumstellar grains. Suitable laboratory data are extremely important for the decoding of astronomical spectra.

Key words: dust, extinction – methods: laboratory: solid state – techniques: spectroscopic

1. Introduction
Dust grains play a central role in the physics and chemistry of practically all astrophysical environments. They influence the thermodynamic properties of the medium and provide a surface for very efficient chemical reactions that are responsible for the synthesis of a major part of important astronomical molecules. Interstellar and circumstellar dust grains are of great interest, as they are the building blocks of planets and remnants of protoplanetary disks. Knowing the properties of grains, we can follow their pathways to larger astronomical bodies and trace back the history of planetary systems.

Dust grains are typically nanometer- to micrometer-sized aggregates of carbonaceous or siliceous particles (Henning & Salama 1998; Draine 2003). In cold cosmic environments, such as dense molecular clouds and the outer parts of circumstellar shells, including the envelopes of evolved stars, protoplanetary disks, and debris disks, dust grains are mixed with molecular ices. Observations and dedicated laboratory experiments have shown that the main constituent of interstellar and circumstellar ices is H2O, with lower fractions of other volatile species (Allamandola et al. 1999; Burke & Brown 2010; van Dishoeck 2014; Boogert et al. 2015).

Dust grains absorb and scatter stellar light and re-emit the absorbed energy. To interpret the astronomical spectra of dust grains, the spectral data on laboratory dust grain analogs are required. The optical properties of grains in different frequency regions are important for the modeling and understanding of the physics in astrophysical environments. The opacity of grains is the basis for the estimation of important astrophysical parameters, such as dust temperatures, mass-loss rates of evolved stars, and the total dust mass in circumstellar shells or molecular clouds.

The infrared (IR) range (wavelength from 700 nm to 1 mm) is one of the most important spectral regions with respect to dust grains because it provides information on the vibrational modes of dust-building structural units; also, it is the range, which is mainly far-IR (wavelength from 0.1 mm to 1 mm), where the emission from interstellar dust is detected. Thus, infrared spectroscopy is the best astronomical and laboratory tool for studying the composition and properties of the cosmic dust and its laboratory analogs.

The optical properties of pure water ice, silicate, and carbon grains have been intensively investigated in the laboratory (Hagen et al. 1981; Kita & Krätschmer 1983; Smith et al. 1994; Dorschner et al. 1995; Henning & Mutschke 1997; Jäger et al. 1998, 2003; Curtis et al. 2005; Jäger et al. 2008; Mastrapa et al. 2008, 2009; Allodi et al. 2014; Sabri et al. 2014; Reinert et al. 2015). The real astronomical grains in cold environments are mixtures of dust and ice, which explains why there is a strong need to study the experimentally optical properties of such mixtures, which are not yet known. One can try to obtain the optical constants of dust/ice mixtures by mixing known pure dust and ice constants using a number of mixing rules, as has been done in a number of works (Mukai & Mukai 1984; Maron & Maron 2008; Min et al. 2016), but the reliability of such approaches is questionable.

The main purpose of this work is to present unique sets of experimental optical data for silicate/water ice mixtures in the mid-IR spectral region at low temperatures, and to check the reliability of different mixing rules for the production of optical data for such mixtures from the optical data of its components, silicates and water ice. The new optical constants of silicate/water ice mixtures published here can be used in models describing molecular clouds and circumstellar shells and in predictions of observable IR features.
2. Experimental Procedure

Amorphous silicate MgSiO_3/water ice mixtures were produced in a device consisting of a laser ablation setup combined with a cryogenic chamber, which is able to condense solid carbonaceous and siliceous grains and gases at temperatures down to 8 K. The setup (without the cryostat) is described in detail elsewhere (Jäger et al. 2008). The gas-phase deposition of nanometer-sized amorphous MgSiO_3 grains was achieved by pulsed laser ablation of a MgSi 1:1 target and subsequent condensation of the evaporated species in a quenching atmosphere of 4 mbar O_2. Condensed grains were extracted adiabatically from the ablation chamber through a nozzle into a second low-pressure chamber (10^{-3} mbar) to decouple the grains from the gas. A second extraction through a skimmer into a third chamber (10^{-6} mbar) generated a particle beam that was directed into a fourth, cryogenic, chamber, where the grains were deposited onto a cold CsI substrate. Water was deposited simultaneously with the grains from a water reservoir through a leakage valve and a capillary tube. All of the depositions were performed in a high vacuum chamber with a base pressure of 9 × 10^{-8} mbar at the temperature of the substrate of 8 K. Such relatively poor vacuum conditions due to the combination of a laser ablation system with the cryogenic chamber led to a deposition of CO_2 from the chamber atmosphere. A CO_2 stretching band is visible in the IR spectra that were recorded. However, the amount of CO_2 is small compared to the amount of the main deposits and cannot influence the optical properties discussed in this study. The deposition time was 20 minutes for all samples. The water deposition rate was a few tens of nm minutes^{-1} depending on the ice thickness. Such a low deposition rate corresponds to the formation of high-density amorphous water ice (Mastrapa et al. 2009).

The thickness of the silicate grain deposit was measured by a quartz crystal resonator microbalance (sensitivity 0.1 nm) using known values for the deposit area and density. The particle beam was divided by an aperture to simultaneously deposit the grains on the microbalance and the substrate. Due to a slight tilt of the beam, the microbalance may not have been completely covered. The uncertainty related to the determination of the area of the deposit on the microbalance is estimated to be about 5%. The thickness of the water matrix was estimated from the 3.1 μm water band area using the band strength of 2 × 10^{-16} cm molecule^{-1} (Hudgins et al. 1993) with an uncertainty of 2%. A 280 nm MgSiO_3 layer and a 640 nm H_2O layer, and two silicate/water ice mixtures with the MgSiO_3/H_2O mass ratios of 0.8 and 2.7, were deposited and studied. Additional measurements were also done for mixtures with the mass ratios of 0.3 and 1.5 to establish the mass-ratio dependence of water trapped at 200 K. The mass ratio was calculated from the thicknesses of the deposits and densities of 1.1 g cm^{-3} for high-density amorphous water ice (Narten 1976) and 2.5 g cm^{-3} for amorphous silicates. For glassy silicates the density of 2.71 was measured (http://www.astro.uni-jena.de/Laboratory/OCDB/index.html). MgSiO_3 grains produced by laser ablation are characterized by less dense structures and show slightly lower values of 2.6–2.5. The thicknesses corresponding to the silicate/ice samples were 280 nm for MgSiO_3 and 800 nm for H_2O (sample with the mass ratio of 0.8) and 180 nm for MgSiO_3 and 170 nm for H_2O (sample with the mass ratio of 2.7).

IR spectra at four temperatures, namely 8, 100, 150, and 200 K, were measured in the transmission mode using a Fourier transform infrared (FTIR) spectrometer (Vertex 80v, Bruker) in the spectral range of 6000–200 cm^{-1} with a resolution of 0.5 cm^{-1}, but will be presented further in the 4500–400 cm^{-1} range because of the noisy low- and high-frequency edges. Due to slight instrumental instabilities of the baseline of the transmission spectra and possible multiple reflections on the silicate/ice layers, there can be artifacts affecting k-values in the ranges, where the k-values are supposed to be close to zero. Each higher temperature (100, 150, and 200 K) was achieved by heating the sample with the rate of 1 K minutes^{-1}. Before taking spectra at 100, 150, and 200 K the samples were allowed to stabilize for 30 minutes. The spectra of CsI substrates recorded before depositions at 8 K were used as reference spectra.

3. Data Proceeding and Calculation of Optical Constants

There are two sets of quantities that are typically used to describe the optical properties: the real and imaginary parts of the complex refractive index n_1 = n + i*k, and the real and imaginary parts of the complex dielectric function (or relative permittivity) ε = ε' + iε'' (Bohren & Huffman 2004). The relations between these two sets are as follows:

$$\varepsilon' = n^2 - k^2, \varepsilon'' = 2nk. \quad (1)$$

Two sets of the n and k constants have been obtained; these are “measured” constants calculated directly from the transmission spectra of the silicate/ice samples, and “effective” constants calculated from the n- and k-values of pure silicate and ice layers using different mixing rules. In both cases the n- and k-values were determined from Kramers–Kronig analysis of the transmission spectra. The reflection and interference losses were taken into account using an iterative procedure described in Hagen et al. (1981):

$$\alpha \equiv 4\pi kv = \frac{1}{d} \left( -\ln \frac{I}{I_0} + \ln \left( \frac{I_{0H2}/I_{02}}{1 + r_{01}r_{12}\varepsilon^{2ir}} \right) \right) \quad (2)$$

$$n(\nu) = n_1^0 + \frac{1}{2\pi^2} \int_0^\infty \frac{\alpha(\nu')}{\nu'^2 - \nu^2} d\nu' \quad (3)$$

where α is the absorption coefficient, I/I_0 is the transmission spectrum, d is the thickness of the sample, ν is the wavenumber, ν' is a running wavenumber in the integral, r_{pq} and I_{pq} are the complex reflection and transmission coefficients of the pq boundary, x = 2πδd/n_1, and n_1^0 is a seed value for the real part of the index of refraction. For water ice, n_1^0 is 1.29 for amorphous H_2O ice (in our case 8 K and 100 K) and 1.32 for crystalline H_2O ice (in our case 150 K and 200 K; Mastrapa et al. 2009). Assuming a starting value for n_1, the absorption coefficient and the imaginary part of the refractive index were calculated from the transmission spectrum according to Equation (2). Then, n, the real part of the refractive index, was calculated by taking the integral in Equation (3) over the measured range because the denominator in Equation (3) gives little weight to contributions to the integral, which are far from ν. With this new refractive index, n_1 = n + i*k, we calculated the transmission spectrum and compared it with the measured one. The procedure was repeated until a 0.1% agreement
between the measured and calculated transmission spectra was achieved.

For the silicate and silicate/ice samples, these calculations were complicated by the porosity introduced by the layer of MgSiO$_3$ particles. Silicate grains are known to be very porous, with a porosity that can be as high as 90% (Sabri et al. 2014). Fortunately, from the interference structures in the IR spectra due to the standing waves arising in the sample, we were able to estimate the total film thicknesses of the porous layers to be 1460 nm for the silicate sample and 2200 and 1200 nm for the silicate/ice samples, with the mass ratios of 0.8 and 2.7, respectively. The thicknesses were determined from the distance between fringes in the spectra. Using these values, Equations (2) and (3) delivered optical constants for the porous layer. Then, we calculated the constants for the inclusions, MgSiO$_3$ or MgSiO$_3$/H$_2$O, in a vacuum using the inverted Maxwell–Garnett formula (see below) and the inverted volume fraction of the inclusions. This procedure delivered $k$ and $n$ for the silicate and silicate/ice samples. In these computations, $n_i^2$ was chosen in such a way that the real parts of the measured optical constants came close to the effective ones after the correction of the porosity.

The effective optical constants were calculated from the $k$ and $n$ spectra of the MgSiO$_3$ and H$_2$O samples using different mixing rules (often called effective medium approaches) for a two-component mixture composed of inclusions (silicate grains) embedded in a matrix (water ice). In the next section we present the results of the application of the Maxwell–Garnett mixing rule working with the following approximations: (i) a mixture that is composed of inclusions embedded in an otherwise homogeneous matrix, (ii) inclusions that are identical in composition but may be different in volume, (iii) inclusions that are separated by distances greater than their characteristic size, and (iv) inclusions that are spherical and small compared to $\lambda$. In this case, the dielectric function of the effective medium can be calculated by the following equation (Bohren & Huffman 2004):

$$\varepsilon_{av} = \varepsilon_m \left(1 + \frac{3f}{1 - f} \left(\frac{\varepsilon_i - \varepsilon_m}{\varepsilon_i + 2\varepsilon_m}\right)^2\right)$$

(4)

where $\varepsilon_{av}$ is average dielectric function, $\varepsilon_m$ and $\varepsilon_i$ are dielectric functions of matrix and inclusions, and $f$ is the volume fraction of inclusions. The effective $n$- and $k$-values were obtained from $\varepsilon_{av}$ using relation 1. The other mixing rules tried were Bruggeman, Lichtenecker, and Looyenga (Maron & Maron 2008).

Thus, for each silicate/ice ratio two sets of optical constants have been obtained: measured constants, calculated from the transmission spectra of the corresponding silicate/ice sample, and effective constants, calculated by mixing the $n$- and $k$-values obtained from the transmission spectra of the MgSiO$_3$ and H$_2$O samples. The measured constants will be published in the Heidelberg-Jena-St.Petersburg Database of Optical Constants (http://www.mpia.de/HJPDQC/) and can be used in astrochemical models and for the decoding of astronomical spectra.

4. Results

The chosen temperatures of 8, 100, and 150 K correspond to different structures of water ice, namely high-density amorphous ice, low-density amorphous ice, and crystalline ice (Hagen et al. 1981; Jenniskens et al. 1995). At a temperature of 200 K, pure water ice (deposited without silicate grains) is completely desorbed from the substrate.

The observed vibrational bands in the spectra are as follows: 3300 cm$^{-1}$ involving symmetric and asymmetric H$_2$O stretching vibrations, 2347 cm$^{-1}$ – CO$_2$ stretching, 2200 cm$^{-1}$ – H$_2$O combination mode, 1640 cm$^{-1}$ – H$_2$O bending, 1040 cm$^{-1}$ – Si–O stretching, 770 cm$^{-1}$ – H$_2$O librational motion, and 520 cm$^{-1}$ – O–Si–O bending. As an example of the measured spectra, transmission spectra of the silicate/ice sample with the mass ratio of 0.8, of the pure MgSiO$_3$ sample, and a pure H$_2$O ice sample at 8 K, can be seen in Figure 1.

![Figure 1. Transmission spectra of the MgSiO$_3$/H$_2$O sample with the mass ratio of 0.8 (red curve), MgSiO$_3$ sample (black curve), and H$_2$O sample (blue curve) at 8 K.](image-url)
stretching vibration and librational motion, and the silicate stretching vibration.

The case of the silicate/ice mixture with the mass ratio of 2.7 is a bit more complicated because of the higher mass and volume fraction of silicates with respect to water ice. One can consider the sample to be silicate inclusions in a water ice matrix (as in the case of the silicate/ice sample with the mass ratio of 0.8), as well as water ice inclusions in a silicate matrix. Bruggeman, Lichtenecker, and Looyenga rules are symmetrical; i.e., the dielectric functions of matrix and inclusions can be exchanged. We have applied the asymmetrical Maxwell–Garnett mixing rules for both silicate/ice mixtures. An example is shown in Figure 3. The differences between the spectra “silicates in ice” and “ice in silicates” are small, but a homogeneous water ice matrix is considered to be more appropriate for the Maxwell–Garnett approach, which requires a homogeneous matrix.

A comparison of the measured $k$ and $n$ constants of the silicate/ice samples with mass ratios of 0.8 and 2.7 with the effective $k$ and $n$ values is presented for different temperatures. The effective constants were obtained by using the Maxwell–Garnett rule for the case of silicate grain inclusions in water ice matrix. Figure 4 presents the optical constants at 8 K for the two silicate/ice mixtures studied. A number of differences between the measured and effective spectra can be observed, namely a redshift, a slight narrowing, and an intensity increase of the stretching vibration of H$_2$O in the measured spectra as compared to the effective ones. One can also observe an

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**Figure 2.** Measured (red curve) and effective $k$ spectra at 8 K: Maxwell–Garnett approach (black), Bruggeman approach (violet), Lichtenecker approach (blue), and Looyenga approach (green). MgSiO$_3$/H$_2$O mass ratio of 0.8 (left) and 2.7 (right). The effective curves practically coincide and the differences are visible only with the enlargement of the figure.

**Figure 3.** Measured (red curve) and effective $k$ spectra of the sample with the MgSiO$_3$/H$_2$O mass ratio of 2.7 at 8 K: water ice as matrix (black), silicate grains as matrix (blue).
increased absorption on the low-frequency (long wavelength) side of the band, which is much more noticeable for the mixture with the mass ratios of 2.7.

The first structural transformation of the ice from high- to low-density amorphous ice expected in the temperature range between 8 and 100 K leads to the typical redshift, narrowing, and intensity increase of the 3300 cm\(^{-1}\) and 1640 cm\(^{-1}\) water bands, a blueshift of the 2200 cm\(^{-1}\) and 770 cm\(^{-1}\) bands, and a decrease of the intensity of the stretching vibration of H\(_2\)O in the measured spectra with respect to the effective ones. This effect is again more noticeable for the sample with mass ratios of 2.7. The optical constants at 100 K are shown in Figure 5.

The conversion of the amorphous into crystalline ice around 140 K leads to the typical redshift, narrowing, intensity increase, and appearance of a substructure in the 3300 cm\(^{-1}\) water band. In addition, a suppression of the stretching vibration band of H\(_2\)O in the measured spectra with respect to the effective ones can be observed. Optical constants of the silicate/ice mixtures at 150 K are presented in Figure 6.

At 200 K we observe water absorption bands in the spectra of all silicate/ice samples, while water ice in the pure H\(_2\)O sample is completely desorbed. An example is presented in Figure 7. The water stretching band observed for the silicate/ice samples is very broad, which could be related to the morphology of the sample as well as to an insufficient baseline correction. A small positive bump in the water spectrum is due to the presence of a low amount of water ice in the reference sample (CsI substrate at 8 K before the deposition). The dependence of the relative (to deposited) remaining amount of water in the silicate/ice samples at a temperature of 200 K on the silicate/ice mass ratio is presented in Figure 8.

5. Discussion

With the approximations of the Maxwell–Garnett mixing rule we can assume that the scattering on the grains is small and the extinction is the same as the absorption. In this case, a useful magnitude for the comparison of astronomical and laboratory measurements is the total absorption cross section (or absorption efficiency \(Q_a\)) of grains (Ossenkopf et al. 1992). It can be taken per unit volume of grains or normalized to the particle radius. A comparison between the absorption efficiencies divided by particle radius, \(Q_a/a\), calculated for small spherical particles in the Rayleigh limit from the measured optical constants is presented in Figure 9. \(Q_a\) was defined as

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**Figure 4.** Effective (black curve) and measured (red curve) \(k\) and \(n\) spectra of the MgSiO\(_3\)/H\(_2\)O mixtures at 8 K with the mass ratio of 0.8 (top) and 2.7 (bottom).
follows (Fabian et al. 2001):

$$Q_a = 2kVlm \left( \frac{\varepsilon}{\varepsilon - \varepsilon_m} \ln \frac{\varepsilon}{\varepsilon_m} \right)$$

where $k$ is the wave vector, $V$ is the volume, $\varepsilon$ is the measured complex dielectric function, and $\varepsilon_m$ is the dielectric function of vacuum.

For the two different silicate/ice composites with dust fractions of 0.8 and 2.7, the ratio between the OH stretching band at ~3 $\mu$m and the Si–O stretching band of silicates at about 9.7 $\mu$m is clearly changing. With increasing temperature, the sample characterized by the lower dust-to-ice ratio of 0.8 shows distinct shifts of the H$_2$O stretching band at 3.1 $\mu$m to longer wavelengths and of the libration band at ~13 $\mu$m to shorter wavelengths. In addition, both bands are getting stronger. The position of the H$_2$O stretching band at the maximum shifts from 3.05 $\mu$m at 8 K to 3.07 $\mu$m and 3.10 $\mu$m at 100 K and 150 K, respectively. In contrast, the libration bands show a short-wavelength drift from 12.78 $\mu$m to 12.34 $\mu$m and 12.01 $\mu$m, for 8 K, 100 K, and 150 K, respectively. With a higher dust fraction of 2.7, the 3.1 $\mu$m band is shifted comparably due to the modification of the ice structure with the temperature, whereas the libration mode is unaffected by the temperature rise. The stretching band position varies from 3.06 $\mu$m, to 3.07 $\mu$m, and 3.10 $\mu$m for the temperatures of 8 K, 100 K, and 150 K, respectively. Consequently, the temperature-related band shift of the H$_2$O stretching band at around 3.1 $\mu$m seems to be independent of the silicate/ice ratio of the sample. The Si–O stretching vibrations shows only negligible changes with the temperature but a weak long wavelength shift of ~0.1 $\mu$m for the sample having a higher dust/ice ratio.

Experiments on various deposition rates of water at 10 K demonstrated that a decrease in the deposition rate shifts the peak frequency to lower frequencies while the bandwidth decreases (Hagen et al. 1981). It was later shown in a number of experiments that a lower deposition rate leads to a denser ice (Berland et al. 1995; Jenniskens et al. 1995). High condensation rates limit the time for lateral diffusion following adsorption, thus producing a lower density film (Berland et al. 1995). Summarizing the results of these studies, we can conclude that the denser the deposited ice, the lower the band frequency and the narrower the band. Thus, in our case, the observed redshift and narrowing of the measured spectra can be linked to the denser water ice in the case of simultaneous deposition of water and silicate grains. The transformation from high-density to low-density ice also shifts the peak frequency to

Figure 5. Effective (black curve) and measured (red curve) $k$ and $n$ spectra of the MgSiO$_3$/H$_2$O mixtures at 100 K with the mass ratio of 0.8 (top) and 2.7 (bottom).
lower frequencies and narrows the band. It was supposed that this transformation requires the breaking of, on average, one hydrogen bond per molecule in the high-density ice structure (Jenniskens et al. 1995), which leads to a strengthening of the rest hydrogen bonds. One more explanation for the observed redshift and narrowing of the measured spectra can be the strengthening of hydrogen bonds due to the interaction with silicate molecules.

Figure 6. Effective (black curve) and measured (red curve) $k$ and $n$ spectra of the MgSiO$_3$/H$_2$O mixtures at 150 K with the mass ratio of 0.8 (top) and 2.7 (bottom).

Figure 7. Transmission spectra at 200 K of the MgSiO$_3$/H$_2$O sample with the mass ratio of 0.8 (red curve) and H$_2$O sample (blue curve).

Figure 8. Dependence of the volume percentage of remaining water in the MgSiO$_3$/H$_2$O samples at 200 K on the MgSiO$_3$/H$_2$O mass ratio.
Obviously, only molecules from the mass ratios 0.8 and 2.7 in the mid-IR spectral region at temperatures of 8, 100, and 150 K. The optical constants were obtained from the transmission spectra of the silicate/ice mixtures and compared with the effective constants calculated from the optical constants of pure silicate grains and pure water ice using the Maxwell–Garnett mixing rule. Differences between measured and effective constants demonstrate that the determination of the optical properties of interstellar and circumstellar icy silicate grains by a mixing of optical constants of water ice and silicates can lead to incorrect results, and underline the importance of conducting further investigations of optical and structural properties of grain/ice mixtures. A trapping of a part of water ice in/on silicate grains at 200 K is detected, and this can improve our understanding of the abundance and desorption properties of interstellar and circumstellar ices and help to develop a link between the dust/ice ratio in a cosmic body and the cosmic environment, from where the body originates. The new optical constants of silicate/water ice mixtures published here can be used in models describing molecular clouds and circumstellar shells and for predictions of observables.

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6. Conclusions

We have presented new sets of experimental optical data of silicate/water ice mixtures with the MgSiO3/H2O mass ratios of 0.8 and 2.7 in the mid-IR spectral region at temperatures of 8, 100, and 150 K. The optical constants were obtained from the transmission spectra of the silicate/ice mixtures and compared with the effective constants calculated from the optical constants of pure silicate grains and pure water ice using the Maxwell–Garnett mixing rule. Differences between measured and effective constants demonstrate that the determination of the optical properties of interstellar and circumstellar icy silicate grains by a mixing of optical constants of water ice and silicates can lead to incorrect results, and underline the importance of conducting further investigations of optical and structural properties of grain/ice mixtures. A trapping of a part of water ice in/on silicate grains at 200 K is detected, and this can improve our understanding of the abundance and desorption properties of interstellar and circumstellar ices and help to develop a link between the dust/ice ratio in a cosmic body and the cosmic environment, from where the body originates. The new optical constants of silicate/water ice mixtures published here can be used in models describing molecular clouds and circumstellar shells and for predictions of observables.

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