

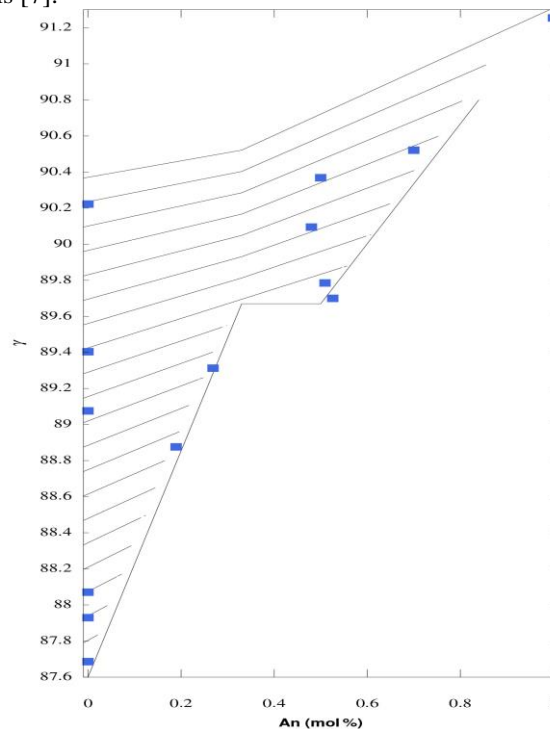
**INFRARED SPECTROSCOPY OF WELL-DEFINED PLAGIOCLASE SAMPLES.** M. P. Reitze<sup>1</sup>, I. Weber<sup>1</sup>, A. Morlok<sup>1</sup>, H. Hiesinger<sup>1</sup>, K. E. Bauch<sup>1</sup>, A. N. Stojic<sup>1</sup>, and J. Helbert<sup>2</sup> <sup>1</sup>Institut für Planetologie (IfP), Westfälische Wilhelms-Universität (WWU), Wilhelm-Klemm-Str. 10, 48149 Münster, Germany, <sup>2</sup>Deutsches Zentrum für Luft- und Raumfahrt (DLR), Rutherfordstr. 2, 12489 Berlin, Germany

**Introduction:** Feldspars are common minerals on planetary bodies, e.g. the Moon or Mercury [1,2]. In order to determine the surface mineralogy of those bodies with remote sensing techniques, detailed knowledge of mid IR spectra of feldspars is necessary. Therefore, we are building a database [2], which includes well-defined mineral spectra and important related information of the samples to provide a high quality “ground truth” for remote sensing application. Thus, all samples presented here have an internal ID which refers to our database. This database will be especially helpful for the MERTIS experiment (Mercury Radiometer and Thermal Infrared Spectrometer), which is onboard BepiColombo on its way to Mercury.

Plagioclase feldspars are the solid solution between the end-members  $\text{Na}[\text{AlSi}_3\text{O}_8]$  (Ab) and  $\text{Ca}[\text{Al}_2\text{Si}_2\text{O}_8]$  (An). They typically contain small amounts of  $\text{K}[\text{AlSi}_3\text{O}_8]$  (Or). The substitution of Na by Ca ions requires a substitution of Si by Al ions to preserve the charge balance. Furthermore, the plagioclase feldspars are characterized by their Al,Si distribution into their four different tetrahedral sites  $T_{10}$ ,  $T_{1m}$ ,  $T_{20}$ , and  $T_{2m}$ . In An feldspars the Al,Si order is perfect at any temperature with alternating Al-Si distribution since Al-Al contacts are energetically unfavorable [3]. Depending on the formation temperature and cooling history, Ab-rich feldspars can occur *ordered* with Al ions occupying the tetrahedral site  $T_{10}$  or *highly disordered* with Al and Si ions randomly distributed over the four tetrahedral sites. Therefore, at high temperatures, a complete solid solution between Ab and An feldspars is possible. At low temperatures, the enrichment of Al in the  $T_{10}$  site on the Ab side of the plagioclase series prevents the formation of a complete solid solution between Ab and An feldspars. In contrast, at low temperatures, three miscibility gaps open during slow cooling ranging from  $\text{An}_{20}$  to  $\text{An}_{25}$  (Peristerite gap),  $\text{An}_{38}$  to  $\text{An}_{62}$  (Bøggild gap), and  $\text{An}_{64}$  to  $\text{An}_{90}$  (Huttenlocher gap). Within these gaps exsolution of the crystals takes place, which is predominantly submicroscopic. [4] introduced the order parameter  $t_{10} - \langle t_{1m} \rangle$  for the plagioclase series with the usage of the  $\gamma$  angle of the unit cell and the An content. Mid-infrared spectroscopy of feldspars is sensitive to both, chemical composition [5] as well as degree of order [6].

Our study investigates changes in infrared spectra resulting in changes of the chemical composition and the degree of order. Both is measurable in the

MERTIS-relevant wavelength region ranging from  $7 \mu\text{m}$  to  $14 \mu\text{m}$ . In addition, detailed knowledge of these effects is necessary to understand space weathering effects and impact-related changes of feldspar minerals [7].



**Fig 1:**  $\text{K}[\text{AlSi}_3\text{O}_8]$  (An) content depending  $\gamma$  angle for all samples and contoured in 0.05 steps from 0 (top) to 1 (bottom) for order parameter  $t_{10} - \langle t_{1m} \rangle$  after [2].

**Methods:** We analyzed seven natural, five heat-treated, and two synthetic plagioclase samples with different chemical compositions. The samples were crushed with a steel or agate mortar and sieved to grain size fraction smaller  $0.25 \mu\text{m}$ ,  $25 \mu\text{m}$  to  $63 \mu\text{m}$ ,  $63 \mu\text{m}$  to  $125 \mu\text{m}$ ,  $125 \mu\text{m}$  to  $250 \mu\text{m}$ , and a fraction larger than  $250 \mu\text{m}$ . The chemical composition of the samples was measured with a JEOL JXA-8530F Hyperprobe electron probe microanalyzer (EMPA) at Institut für Mineralogie (IfM) at the WWU. Order parameters were determined on the basis of Rietveld refined X-ray powder diffractograms with Si internal standard measured with a Philips X’Pert diffractometer equipped with a primary Ge monochromator at the IfM and a BRUKER D8 advance at Münster Electrochemical Energy Technology (MEET). Infrared spectra were measured using a Bruker Vertex 70v at the IfP, equipped with a varying angle unit A513, which allows

to measure bidirectional reflectance measurements with varying observation geometries. All samples were measured at approx. 23°C and a pressure of 2 hPa. The reflectance was calculated by dividing the sample single channel spectrum (calculated with the mean of 512 scans) by that of a diffuse gold standard (INFRAGOLD™).

All infrared spectra presented here refer to the grain size fraction from 63 µm to 125 µm and an observation geometry with an angle of incidence (i) of 20° and angle of emergence (e) of 30°.

We analyzed the wavelength of the Christiansen feature (CF) and the width  $w$  of the autocorrelation function of different wavelength bands. Autocorrelation of distinct spectral bands was successfully applied in order to determine the degree of order within transmission spectra of Al,Ge feldspars [6].

**Results:** Fig. 1 shows all samples depending on their An content and their gamma angle. The plot is contoured in 0.05 steps from 0 (in the upperpart of the diagram) to 1 (at the lower left corner) with the value of  $t_{10} < t_{1m} >$  after the equations given in [4].

Fig. 2 shows the infrared spectra of the samples presented in Fig. 1 from An<sub>0</sub> (top) to An<sub>100</sub> (bottom). The two dotted lines mark the position of the CF of pure low albite (ID 125 7.73 µm) and synthetic anorthite (ID 126 8.12 µm). The CF shift is only depending on the An content [5,8]. The gray shaded region indicates the measuring range of MERTIS. In this wavelength region strong changes occur. The Reststrahlen bands (RB) in this region tend to broaden and lose

overall reflectance intensity. ID 167 albite is a highly disordered sample (An<sub>0</sub>), produced through heating of the ID 125 sample (An<sub>0</sub>), which shows no clear CF shift but a large broadening and lose of features related to disorder. Therefore, the infrared spectra are not only affected by the An content but also strongly by the distribution of Al and Si ions on the different tetrahedral sites.

**Conclusion:** The spectra presented here clearly show changes due to chemical composition as well as degree of order of the feldspar samples. Especially the spectra of An<sub>0</sub> samples ID 125 and ID 167 which have a different degree of order of the Al,Si distribution, demonstrate the need of understanding the changes of infrared reflectance spectra due to the two different processes. Further results of autocorrelation will be presented at the conference

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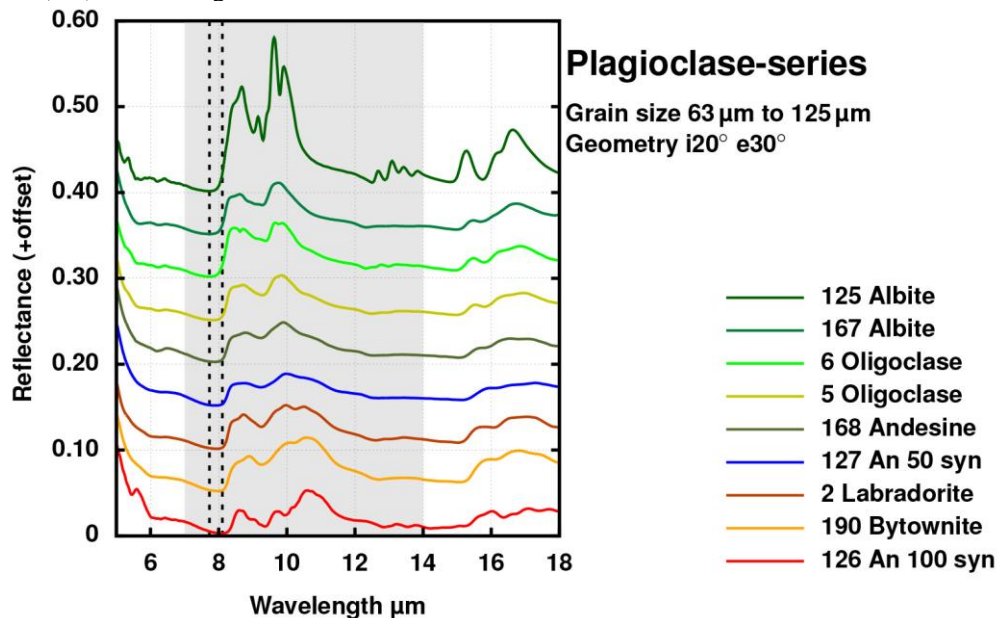


Fig 2: Mid-IR spectra of plagioclases with different chemical composition and degree of order. The two dotted lines indicate the shift of the CF depending on the An content. The gray region indicates the measuring range of MERTIS. RB in this region are effected by both, chemical composition as well as degree of order. IDs refer to the infrared database at the IfP in Münster [9]