MID-INFRARED SPECTROSCOPY OF EXPERIMENTALLY SHOCKED MURCHISON CM2 SAMPLES: COMPARISON WITH ASTRONOMICAL OBSERVATIONS OF CIRCUMSTELLAR DUST.

A. Morlok[1], C. Koike[2], N. Tomioka[1], K. Tomeoka[1], [1]Department of Earth and Planetary Sciences, Faculty of Science, Kobe University, Nada, Kobe 657-8501, Japan <morlok70@kobe-u.ac.jp> [2]Kyoto Pharmaceutical University, Yamashina, Kyoto 607-8412, Japan.

Introduction: Planetesimal collisions are regarded to be one of the major processes of dust formation in the debris disk phase of evolving young stars (e.g.[1]). Astronomical infrared observations allow us to obtain mineralogical information about micron-sized dust in such objects, and thus give us insight into the dust formation processes and the dust itself [2, 3].

To interpret astronomical infrared data, laboratory spectroscopic measurement of dust analogs is a fundamental approach. Previously, such studies have mainly focused on terrestrial and synthetic minerals [e.g. 4]. Since planetesimals in evolving young stars possibly consist of materials similar to those in our early solar system, infrared spectra from meteorites would provide a more favorable source of information.

If dust is produced by impacts on planetesimals, it would go through significant shock processes. Thus we believe that it is of fundamental importance to understand how the shock affects the infrared properties of planetesimal components. Here we present the results of mid-infrared spectroscopic measurements of the experimentally shocked hydrated carbonaceous chondrite, Murchison (CM2). The previous shock experiments [5, 6] suggested that hydrated asteroids produce dust particles during collisions at a much higher rate than anhydrous asteroids. We focus on matrix materials, which, due to its high volatile contents and porosity, is probably the main source of dust in the size range (sub-micron to micron) that can be observed in the mid-infrared region [5, 7].

Samples and Techniques: The Murchison samples studied here were recovered from the previous shock experiments [6] that were performed by using a single stage propellant gun. The Murchison samples shocked at peak pressures of 10, 21, 26, 28, 30, 34, 36 and 49 GPa were subjected to the present infrared measurements. Details about the shock experiments are described in [6].

Matrix materials identified on backscattered electron maps were separated and compressed to fine, submicron powder using a diamond compression cell [8]. Mid-infrared transmission/absorption spectra (2.5 µm to 25.0 µm) were taken using a Nexus 670 FTIR infrared microscope at Kyoto Pharmaceutical University, using a spectral resolution of $4cm^{-1}$. Spectra from the samples that apparently contain major amounts of non-matrix materials (e.g. olivine or carbonates) were omitted.

Results (Fig.1a): The matrix from the unshocked Murchison sample shows a typical phyllosilicate peak at ~10.0 µm, reflecting the dominant presence of serpentine. In the 10 GPa sample, the peak at ~10.0 µm shifts to ~9.8 µm. With increasing shock pressure from 21, 26, 28, 30 to 34 GPa, the 9.8 µm peak becomes narrower and 'sharper', and a shoulder at ~11.0 µm turns into a peak at ~11.2 µm. The 9.8 µm peak is characteristic of an amorphous SiO_2 phase [9]. The 11.2 µm peak is the strongest feature of forsterite [4, 8].

At 36 GPa, the ~11.2 µm forsterite band becomes the strongest, while the ~10.0 µm feature disappears. Instead, a broad peak appears in the range between ~10.0 and ~10.6 µm. The spectrum of the sample shocked at 49 GPa has a strong peak at ~11.3 µm and a second, weaker peak at ~10.2 µm. These are probably bands of iron-rich olivine [4]. At pressures up to 34 GPa, the spectra show water bands at ~3.0 µm. However, at 36 GPa, the water band becomes weak, and at 49 GPa, it disappears.

Discussion: The systematical changes in the infrared spectral features from the samples shocked at 10-49 GPa are consistent with the changes in mineralogy observed in the earlier studies [6,10]. At 10-36 GPa, serpentine and tochilinite in the original matrix break down to Si-rich glass and minor amounts of magnetite and Fe sulfide, being consistent with the sharp band at ~9.8 µm. At 21-36 GPa, the samples respond to shock with comminution and disruption. Thus the matrix becomes a complex mixture of original matrix materials and fragments of chondrules and AOIs. The increasing relative strength of the 11.2 µm (olivine) band with pressures from 21 to 36 GPa reflects the increasing amounts of olivine being mixed into the matrix. At 49 GPa, the sample shows the features of iron-rich olivine, recrystallized from completely molten matrix. We distinguish the following four groups of spectra, based on the shock stages:

I. **Unshocked/Weakly Shocked Material (0 and 10 GPa) –** dominated by a broad peak at ~10.0 µm.

II. **Moderately Shocked (21 to 34 GPa) –** A sharp peak at ~9.8 µm and an emerging peak at ~11.2 µm.

III. **Highly Shocked (36 GPa) – A** strong peak at ~11.2 µm and a broad peak between ~10.0 µm and ~10.6 µm.

IV. Recrystallized/Melted (49 GPa) –A strong peak at~11.3 μm and a weak peak at ~10.2 μm.

Comparison to Astronomical Spectra (Fig.1b): The spectrum of HD 142666, which is an old Herbig star (6.3 My [11]), is characterized by a strong, rounded feature at ~10.0 μm and a smaller, sharp feature at ~11.3 μm. A mixture of the Murchison samples at stages I and II may give a similar spectrum in the mid-infrared region. However, astronomical spectra in the 2.5-3.5 μm region [12] show no water bands, in distinction to the stage II samples that still have significant water features in this region.

The dust around the >10 My old Herbig star HD 144432 [11] has a strong peak at ~10.0 μm and a shoulder at ~11.3 μm, resembling the spectra of the Murchison samples at stage II.

Herbig star HD 100546 (older than 10 My [11]) shows only a strong feature at ~11.3 μm with a weak shoulder at ~10.0 μm. In this case, a mixture of the Murchison samples at stages III and IV provides a good fit.

Conclusions: Mid-infrared spectra of matrix material from shocked Murchison CM2 samples show significant changes with increasing shock pressure. They can be related to the changes in mineralogy – formation of Si-rich glass and olivine, decomposition and dehydration of serpentine and tochilinite with increasing pressure. Comparison of these spectra with astronomical spectra of evolving young stars allow us to deduce the nature of dust and its parent bodies in those stars. In particular, the spectra of evolving disks like HD 142666, HD 144432 and HD 100546 show a similarity to the moderately and highly shocked meteorite samples in the mid-infrared region, which may indicate ongoing heavy collisional events in those debris disks.

Our future work will include further investigations of CM- and CI-type materials, to cover a wider and more representative range of source materials. Further analysis of features in the near and far-infrared regions is also needed to confirm the similarities, especially in relation to the water features.

References: [1] Mann, I. et al. (2006) *Astron. Astrophys. Rev.* 13, 159-228. [2] Okamoto K. O. et al. (2004) *Nature, 431*, 660–663. [3] Bouwman J. et al. (2005) *A&A, 401*, 577–592. [4] Koike et al., (2003) *A&A*, 399, 1101-1107. [5] Tomeoka et al. (2003) *Nature* 423, 60-62. [6] Tomeoka et al. (1999) *GCA* 63, 3683-3703. [7] Flynn and Durda (2004) *PSS* 52, 1129-1140. [8] Morlok et al. (2006) *MAPS* 41, 773-784. [9] Jäger et al., *A&A*, 408, 193-204. [10] Tomioka et al. (2007) *MAPS* in press. [11] van Boekel et al. (2005) *A&A* 437, 189-208. [12] Sloan et al. (2003) *APJ Suppl.*, 147, 379-401.

Acknowledgements: We want to thank Roy van Boekel for providing the spectra of HD 100546, HD 142666 and HD 144432.

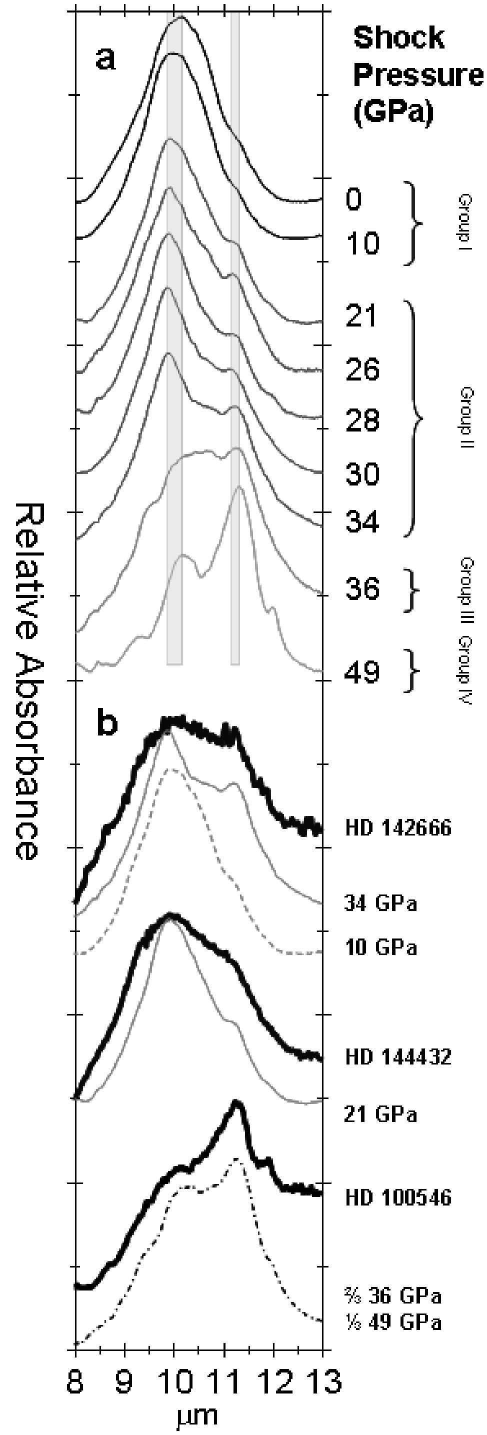

Figure 1: (a) Mid-infrared absorption spectra of Murchison CM2 matrix materials shocked up to 49 GPa. The grey bars show the shift of characteristic bands. (b) comparison with astronomical spectra.