LASER MICROPROBE NOBLE GAS ANALYSIS OF CHONDRULES IN THE NWA 801 CR2 CHONDRITE. S. Matsuda[1], D. Nakashima[1], H. Iio[1], K. Bajo[1], and K. Nagao[1], [1]Laboratory for Earthquake Chemistry, Graduate School of Science, University of Tokyo, Hongo 7-3-1, Tokyo 113-0033, Japan (matsuda@eqchem.s.u-tokyo.ac.jp).

Introduction: Chondrules were formed by rapid cooling of silicate melt about 4.6 Ga, and have held their spherical shapes until to the present. Chondrules are free from trapped noble gases [e.g., 1], which is believed to be due to complete degassing during the chondrule formation. Owing to the absence of trapped noble gases, cosmogenic noble gases can be detected clearly. Cosmogenic noble gases were produced via irradiation of cosmic-rays on surface of the meteorite parent body and during transit to the earth of the meteoroid. Noble gas analysis of chondrules is capable of revealing the exposure histories of the chondrules.

We performed a laser microprobe noble gas analysis of the NWA 801 CR2 chondrite, which contains significant amounts of solar wind (SW) noble gases [2] and has large chondrules (0.5 - 2.5 mm in diameter). Chondrules in NWA 801 contain various concentrations of cosmogenic ^{3}He and ^{21}Ne, which reflects condition for cosmic-ray exposure on their parent body. In addition, we found SW-like noble gases in a chondrule.

Laser microprobe noble gas analysis: We prepared a polished thick section (approximately 300 μm thick) of NWA 801 for noble gas analysis. The thick section was observed with a scanning electron microscope (SEM) so as to examine chondrule textures and major element compositions. Both sides of the thick section were examined by an optical microscope to confirm which cut surfaces of the chondrules were smaller. A Nd-YAG laser beam (50 μm in diameter, five pits) was shot toward the smaller cut surface of the chondrules to extract noble gases contained only in the chondrules, because matrix contains high concentrations of solar noble gases [2]. Noble gases in matrix portions surrounding chondrule were extracted by the same method for comparison. Extracted noble gases were analyzed with the modified VG5400 MS-II noble gas mass spectrometer at the University of Tokyo. We analyzed 5 - 18 sites for individual chondrules (named as CH1 - CH8). After the noble gas analysis, we observed the back sides of each chondrule to confirm the diameters of pits (10 - 50 μm) and estimated fused volumes (2.1 - 5.9 × 10^{-4} mm^3). The concentrations of noble gases are calculated based on the fused volumes and densities of chondrule and matrix (3.2 and 2.8 g/cm^3, respectively). We cannot estimate the concentrations of noble gases in the three chondrules (CH6, CH7, and CH8), because the fused pits in the three chondrules did not penetrate through out the thick section.

Results: The analyzed chondrules include five magnesian porphyritic, a ferroan porphyritic, an Al-rich, and a barred olivine chondrules. Isotopic ratios of He and Ne in the most chondrules are explained by cosmogenic component and radiogenic ^{4}He. Ne three-isotope plot (Fig. 1) shows that Ne in the most chondrules is mainly cosmogenic. On the other hand, noble gases in matrix are dominated by SW component. Solar noble gases in matrix are reported in [2].

Trapped Ne is observed in a porphyritic chondrule composed of olivine with Fe-Mg zoning and Ca-rich plagioclase (CH 1; Fig. 1). The extrapolation of the regression line to the trapped Ne yields solar ^{20}Ne/^{22}Ne ratio of ~ 12 (Fig. 1). The highest ^{20}Ne/^{22}Ne ratio of 7.24 ± 0.09 is observed in a site near the chondrule edge, where the concentration of trapped ^{20}Ne is (1.7 ± 0.2) × 10^{-6} cm^3STP/g and is about 15 times higher than those in the central parts of chondrule free from trapped noble gases. He isotopic ratio at the chondrule edge is (6.3 ± 0.1) × 10^{-4}, suggesting a contribution of solar He (0.00044; [3]). At only one site in CH1, where solar He and Ne are detected, Ar isotopic ratio also shows contribution of SW component as ^{40}Ar/^{36}Ar = 75.0 ± 22.6. In the chondrule CH1, the solar like noble gases are observed in the one portion near the edge, but not in other portions.

Experimental uncertainties for the concentrations and isotopic ratios of Ar in chondrules became large, because of the small mass ablated by the laser.

Discussion: NWA 801 should have experienced two cosmic-ray exposure stages: exposure on the parent body (parent-body exposure) and exposure in space during transit from parent body to the earth (space exposure). The noble gas analysis and petrologic observation show that NWA 801 and 852 are pair meteorites [2]. The concentration of ^{21}Ne produced in matrices during the space exposure ($^{21}Ne_S$) is estimated approximately as 1.9 × 10^{-8} cm^3STP/g and the space exposure age is calculated as ~ 9 Ma [2].

Concentrations of cosmogenic ^{21}Ne in the chondrules and matrix are higher than that of $^{21}Ne_S$ and have a variation (3.9 - 29.4 × 10^{-8} cm^3STP/g; Fig. 2). The difference of chemical composition among the chondrules and matrix possibly affect the production of cosmogenic ^{21}Ne. However, the variation in cosmogenic ^{3}He concentrations (1.3 - 12.6 × 10^{-7}

cm^{3}STP/g) seems to correspond to that in cosmogenic ^{21}Ne (Fig. 2). In addition, cosmogenic ^{3}He concentrations in the chondrules and matrix are also higher than that of ^{3}He$_S$ (1.4×10^{-7} cm^{3}STP/g), which is estimated from the space exposure age of 9 Ma and the ^{3}He production rate (1.6×10^{-8} cm^{3}STP/g/Ma). The production rate of cosmogenic ^{3}He is hardly influenced by the chemical composition. So, the chemical composition is not main reason for the cosmogenic ^{3}He and ^{21}Ne variation and the excesses from ^{3}He$_S$ and ^{21}Ne$_S$. The production rates of cosmogenic ^{3}He and ^{21}Ne depend on the shielding depth against the cosmic-ray irradiation. However, the variation of shielding effects among the chondrules would be negligible small, because the all the measured chondrules are inside the small sample of approximately $8 \times 8 \times 0.3$ mm^3. The space exposure ages of the chondrules and matrix are supposed to be the same during the meteoroid flight. Thus, cosmogenic noble gas excesses and the variations cannot be explained by space exposure, and are explained by cosmic-ray exposure on the parent body.

Most of the chondrules in NWA 801 are free from trapped noble gases, suggesting that the noble gases in precursor substance were completely degassed during the chondrule formation. To the contrary, the trapped solar like noble gases are discovered in the chondrule CH1. Okazaki et al. [5] discovered the Ar-rich trapped noble gases in chondrules in an enstatite chondrite. The Ar-rich gases are explained by incomplete degassing of implanted solar gases during the chondrule formation [5]. In addition, a chondrule in NWA 852 (paired with NWA 801) contains solar like noble gases, which is explained by solar gas acquisition before/during the chondrule formation [6]. The same mechanism might be possible for explanation of the solar gas bearing chondrule (CH1). Since relict grains are contained in CH1, the relict grains might be a carrier of the solar noble gases. However, matrix of NWA 801 contains high concentrations of solar noble gases. The solar noble gases in matrix might have diffused into the chondrule. Thus, acquisition process of the solar gases in the chondrule is still enigmatic.

References: [1] Nakamura T. et al (1999) *GCA, 63*, 341-255. [2] Nakashima D. et al (2009a) this volume. [3] Grimberg A. et al. (2008) *GCA, 72*, 626-645. [4] Walker R. M. (1980) *Proc. Conf. Ancient Sun* (Pepin, R. O., Eddy, J. A., and Merrill, R. B., eds.), 11-28. [5] Okazaki R. et al. (2001) *Nature 412*, 795-798. [6] Nakashima D. et al (2009b) this volume.

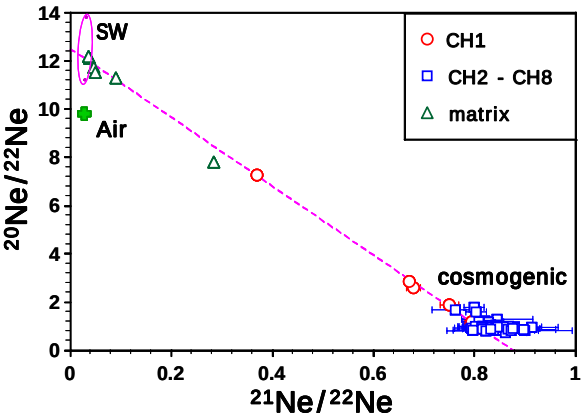

Fig. 1: Neon three-isotope plot of a chondrule containing trapped noble gases (CH1), other chondrules (CH2 - CH8) and matrix in NWA 801. The dotted line is the regression line of the data of CH1.

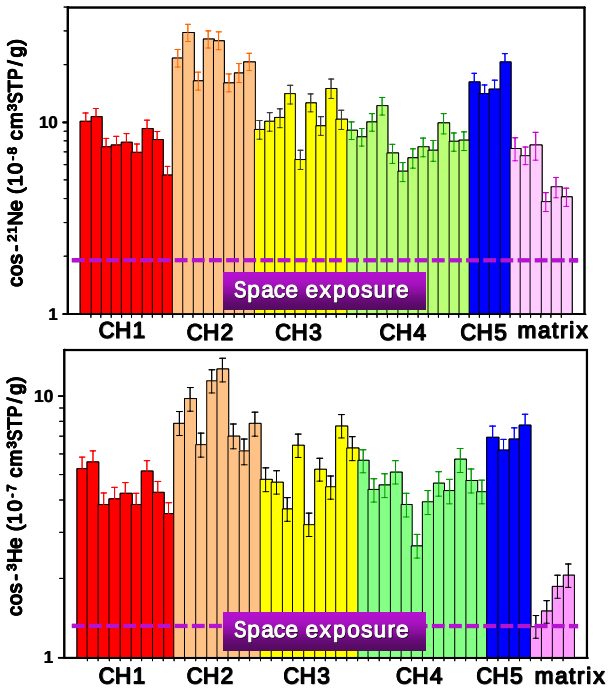

Fig. 2: Concentrations of cosmogenic ^{21}Ne and ^{3}He in five chondrules and matrix. The dotted lines indicate the concentrations of cosmogenic ^{21}Ne and ^{3}He in matrix produced during the space exposure (^{21}Ne$_S$ and ^{3}He$_S$) [2]. Concentrations of cosmogenic ^{21}Ne and ^{3}He in CH6, CH7, and CH8 are not shown.