SOLAR WIND LIKE NOBLE GASES IN A CHONDRULE IN THE NWA 852 CR2 CHONDRITE. D. Nakashima[1], S. Matsuda[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 (naka@eqchem.s.u-tokyo.ac.jp).

Introduction: Chondrules are free from trapped noble gases [e.g., 1], which is attributed to complete degassing during the chondrule formation. However, Okazaki et al. [2] discovered the Ar-rich trapped noble gases in enstatite chondrite chondrules. The Ar-rich gases were formed via incomplete degassing (He and Ne depletion) of implanted solar gases during the chondrule formation [2]. Since solar winds cannot penetrate the solar nebula [3], the chondrule precursors should have been located at the inner edge of the solar nebula to acquire the solar gases, suggesting the chondrule formation near the Sun [2]. Thus, noble gases would have a clue for the formation location of the chondrules, although chondrules are the high temperature products.

We found through laser extraction noble gas analysis of the NWA 852 CR2 chondrite [4] that a chondrule contains solar wind like noble gases in its interior. Here we focus this result and discuss possible acquisition process of the solar wind like noble gases.

Laser extraction noble gas analysis: A polished thick section (~ 300 µm thick) of NWA 852 was prepared for SEM observation followed by noble gas analysis. Noble gases were extracted with a Nd-YAG laser (~ 30 µm in diameter). For one measurement of the individual sites of the chondrule, twenty five pits were made (fused mass is approximately 16 µg by assuming ρ is ~ 3 g/cm^3). Extracted noble gases were analyzed with a noble gas mass spectrometer (MS-III) at University of Tokyo.

Three-dimensional image of the analyzed chondrule was obtained using synchrotron radiation X-ray CT at BL20B2 of SPring-8, with X-ray energy of 27 keV and pixel size 2.74 µm. Laser pits and internal texture of the chondrule were observed. Noble gas data, of which laser pits grazed matrix, were excluded (not surrounded by dashed lines in Fig. 1), because matrix contains high concentrations of solar noble gases [4].

Results: The chondrule shows porphyritic texture and consists of Mg-rich olivine, low-Ca pyroxene, and Ca-plagioclase, suggestive of a type IAB chondrule. Helium and neon isotopic ratios of the most sites of the chondrule are explained by cosmogenic component and radiogenic ^{4}He (Fig. 1). The inner sites of the chondrule appear to show a solar contribution. Trapped ^{20}Ne/^{22}Ne ratio of the chondrule is estimated as 12.6 ± 0.5, which is within the solar Ne range (11.2 - 13.8; [5]). Concentrations of ^{4}He and ^{20}Ne in the inner sites are 5 - 10 times higher than those in the outer sites (Fig. 1). High concentrations of the light noble gases are characteristic for solar noble gas bearing specimens.

The ^{36}Ar concentrations are ~ 0.6 - 7.3 × 10^{-8} cm^3/g, and much lower than those in enstatite chondrite chondrules [2]. Ar isotopic ratios of the inner sites are indicative of solar Ar contribution, but considering large errors, solar Ar has yet to be definitely determined. The same is true for Kr and Xe.

Trapped ^{4}He/^{20}Ne ratios (1500 - 2200) of the inner sites are higher than that of solar winds (~ 500; [5]), which is attributed to elemental fractionation in He/Ne ratio during laser extraction, because of low gas retentivity of He [1]. The trapped ^{20}Ne/^{36}Ar ratios of inner sites are 3 - 13. The higher ^{20}Ne/^{36}Ar ratio than 1 is characteristic for solar noble gas bearing specimens. Thus, noble gases signatures of the chondrule interior have similarities to solar wind noble gases.

Cosmogenic ^{3}He and ^{21}Ne concentrations in the inner sites are comparable with those in the outer sites, considering errors. The averaged cosmogenic ^{21}Ne concentration (4.8 × 10^{-8} cm^3/g) is higher than the concentration of cosmogenic ^{21}Ne produced during the transit to the earth (~ 1.9 × 10^{-8} cm^3/g in matrix [4]), suggesting the additional ^{21}Ne production during the cosmic-ray exposure on the parent body.

Discussion: Since solar winds can penetrate only less than 1 µm [6], direct implantation into the chondrule interior (~ 700 µm) is unlikely. Solar noble gas diffusion from surrounding matrix might be possible, because the chondrule is a part of the solar gas rich meteorite [4]. In this case, the solar gases needed to diffuse into the chondrule interior followed by diffusive loss from the outer sites. Since the diffusion coefficient of ^{4}He is much higher than that of ^{20}Ne (more than 100 times higher in case of olivine; [7]), ^{4}He should be completely lost while ^{20}Ne moves from the interior to the surface (~ 500 µm). Solar-like He in the chondrule interior cannot be explained by diffusion. Thus, solar gas acquisition after the chondrule formation is unlikely. In addition, most chondrules that we analyzed are free from solar gases, indicative of almost no solar gas diffusion into the chondrule interiors [8].

Solar like noble gases in the chondrule interior would have been acquired before/during the chondrule formation. Since solar winds cannot penetrate the nebular gases [3], the chondrule precursor had been transported to the inner edge of the nebular disk so that the precursor had acquired solar like noble gases. If the absence of solar gases from the chondrule outer sites resulted from the diffusive loss during the chondrule formation, solar-like He should also have been lost from the interior, because of the reason noted above. It is inferred that the solar like noble gases are preserved in a phase with high noble-gas-retentivity, like metal. The X-ray CT images show that some laser pits of the chondrule interior graze small metal-like grains (30 - 100 μm), which might be a possible carrier of the solar wind like noble gases.

Considering our result and the Ar-rich noble gases in enstatite chondrite chondrules [2], chondrules may preserve trapped noble gases with various compositions, and it is expected that chondrules in other chondrites retain the trapped solar like noble gases.

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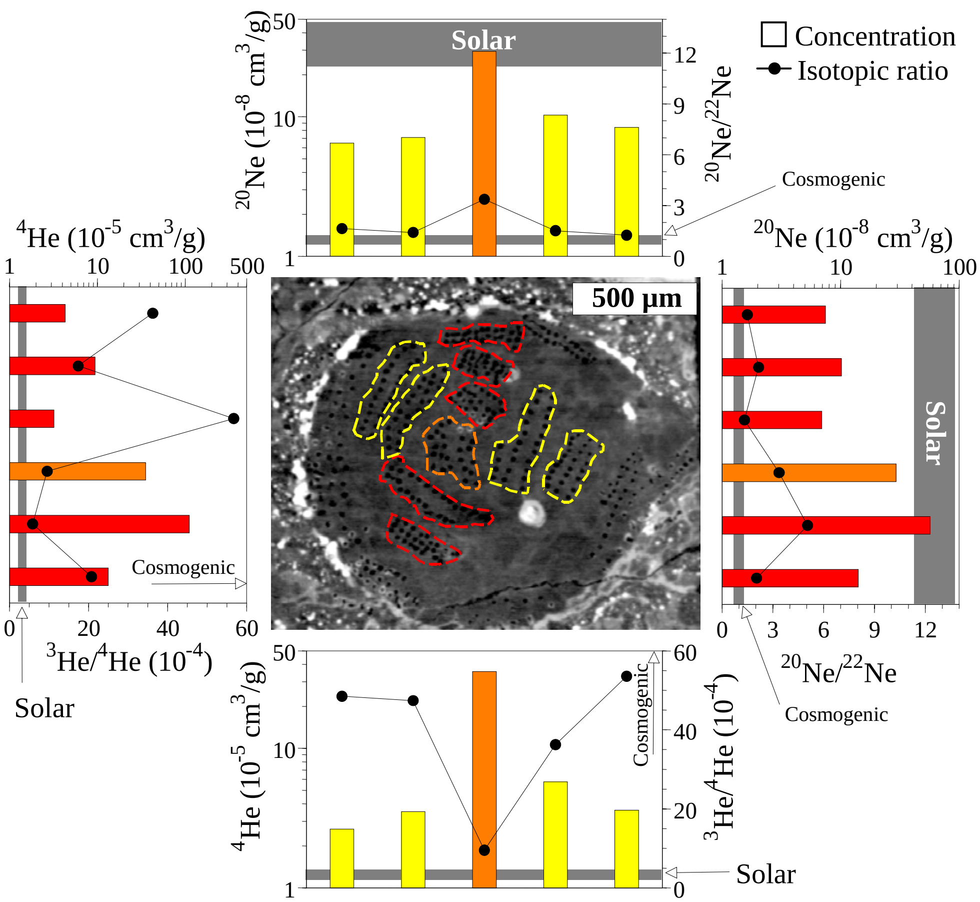

Fig. 1: An X-ray CT image of a chondrule in NWA 852 (Center). Small black dots are laser pits, and the surrounding dashed lines indicate measurement sites. Graphs on all four sides of the X-ray CT image show concentrations and isotopic ratios of He and Ne (bar charts are concentrations, and line charts are isotopic ratios). The orange, yellow, and red bars are correspondently related to the measurement sites surrounded by the orange, yellow, and red dashed lines.