SYNCHROTRON RADIATION XRD ANALYSIS OF INDIALITE IN YAMATO-82094 UNGROUPED CARBONACEOUS CHONDRITE. T. Mikouchi[1], K. Hagiya[2], N. Sawa[2], M. Kimura[3], K. Ohsumi[4], M. Komatsu[5,6], M. Zolensky[7], [1]Dept. of Earth and Planetary Science, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, [2]School of Science, University of Hyogo, Koto, Kamigori-cho, Ako-gun, Hyogo 678-1297, Japan, [3]Faculty of Science, Ibaraki University, Bunkyo, Mito, Ibaraki 310-8512, Japan, [4]Japan Synchrotron Radiation Research Institute (JASRI), Koto, Sayo-cho, Sayo-gun, Hyogo 679-5198, Japan, [5]Graduate University for Advanced Studies (SOKENDAI), Hayama-cho, Miura-gun, Kanagawa 240-0193, Japan, [6]Dept. of Earth Science, Waseda University, Nishiwaseda, Shinjuku-ku, Tokyo 169-8050, Japan, [7]XI2, NASA Johnson Space Center, Houston, TX 77058, USA, E-mail: mikouchi@eps.s.u-tokyo.ac.jp.

Introduction: Yamato-82094 (Y-82094) is an ungrouped type 3.2 carbonaceous chondrite, with abundant chondrules making 78 vol.% of the rock [1]. Among these chondrules, an unusual porphyritic Al-rich magnesian chondrule is reported that consists of a cordierite-like phase, Al-rich orthopyroxene, cristobalite, and spinel surrounded by an anorthitic mesostasis [2]. The reported chemical formula of the cordierite-like phase is $Na_{0.19}Mg_{1.95}Fe_{0.02}Al_{3.66}Si_{5.19}O_{18}$, which is close to stoichiometric cordierite ($Mg_2Al_3[AlSi_5O_{18}]$). Although cordierite can be present in Al-rich chondrules [3], it has a high temperature polymorph (indialite) [4] and it is therefore necessary to determine whether it is cordierite or indialite in order to better constrain its formation conditions. In this abstract we report on our synchrotron radiation X-ray diffraction (SR-XRD) study of the cordierite-like phase in Y-82094.

Methods: We studied a thin section of Y-82094 by energy-scanning SR-XRD which we developed at SPring-8, Hyogo, Japan [5]. At beam line BL37XU an undulator is installed and white undulator radiation is further monochromatized using a Si (111) double-crystal monochromator. A Kirkpatrick and Baez mirror is equipped upstream of the sample giving a beam size of ~0.7 x 2 μm on the sample position. Diffraction patterns were measured on the two-dimensional detector (CMOS Flat panel detector, Hamamatsu Photonics K.K.). The thin section analyzed was attached on the XYZ-stage, and the target point was adjusted on the micro-beam position under an optical microscope. We applied energies from 30.00 to 20.00 keV (λ=0.4133-0.6199 Å) at steps of 40 eV with each exposure time being 0.5 seconds to obtain diffraction data without rotating the sample.

Results: We could obtain sharp diffraction spots from the core of a cordierite-like phase in Y-82094 (Figs. 1, 2). Such sharp diffraction spots are consistent with relatively low shock grade (S2) of the meteorite [1]. The obtained diffraction pattern was analyzed by using the parameters of the indialite crystal structure [6] because it is likely that this Al-rich chondrule was formed at high temperature where indialite is stable over cordierite [4]. We found that the calculated diffraction pattern employing the indialite structure gave the best match, with the observed diffraction spots and the calculated indices being shown in Fig. 3. Then, 57 strong diffraction spots were used to refine the cell parameters. The obtained cell parameters are: a = 9.800(3) Å, b = 9.792(2) Å, c = 9.330(2) Å, α = 89.99(3)°, β = 90.09(5)°, γ = 120.00(2)°, a/b = 1.0009(4). These are very close to the literature data of indialite (hexagonal, space group: $P6/mcc$, a = 9.800(3) Å, c = 9.345(3) Å, $\alpha = \beta$ = 90°, γ = 120° [6])

Discussion and Conclusion: The crystal structures of cordierite and indialite are highly related because distortion of the indialite cell (hexagonal) gives the cordierite cell (orthorhombic, space group *Cccm*, a = 17.079(3) Å, b = 9.730(2) Å, c = 9.356(2) Å [7]) [e.g., 4]. Before we worked on SR-XRD, we tried both Raman analysis and electron back-scatter diffraction (EBSD) using FEG-SEM [2]. However, we could not clearly distinguish between cordierite and indialite because of their structural similarity. The SR-XRD study of the cordierite-like phase in an unusual Al-rich chondrule in Y-82094 revealed that the obtained diffraction pattern could be indexed by the indialite structure. The successful indexing using the hexagonal cell means that the phase is indialite rather than cordierite.

Cordierite is a common mineral in terrestrial metamorphic rocks, but an extremely rare phase in extraterrestrial samples. The few reports of cordierite include cordierite-spinel troctolite known in lunar highland rocks [8], the Allende CV3 chondrite [9, 10], and a mesosiderite [11]. Indialite has never been found in extraterrestrial samples although cordierite in Allende is reported to be “hexagonal cordierite” [9].

The stability field of indialite is not well constrained, but [4] and [12] reported that indialite is stable above 1450 ºC. This is consistent with the occurrence of cristobalite in this chondrule. Such high temperature is quite normal during Mg-rich chondrule formation. Thus, if a cordierite-like phase is found in

CAIs or Al-rich chondrules, it is expected to be indialite as revealed in this study.

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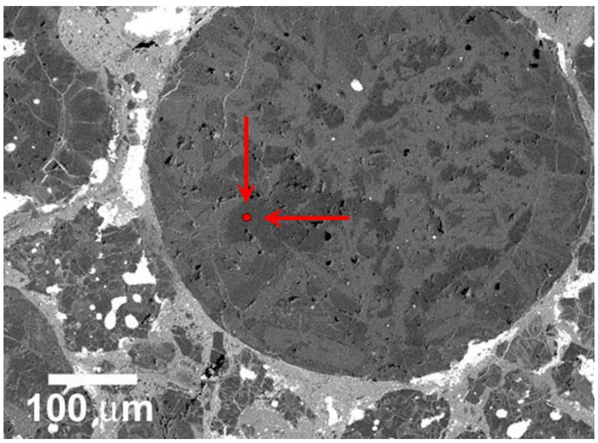

Fig. 1. Back-scattered electron image of Al-rich chondrule in Y-82094. The analyzed point is shown as a small red circle indicated by two arrows.

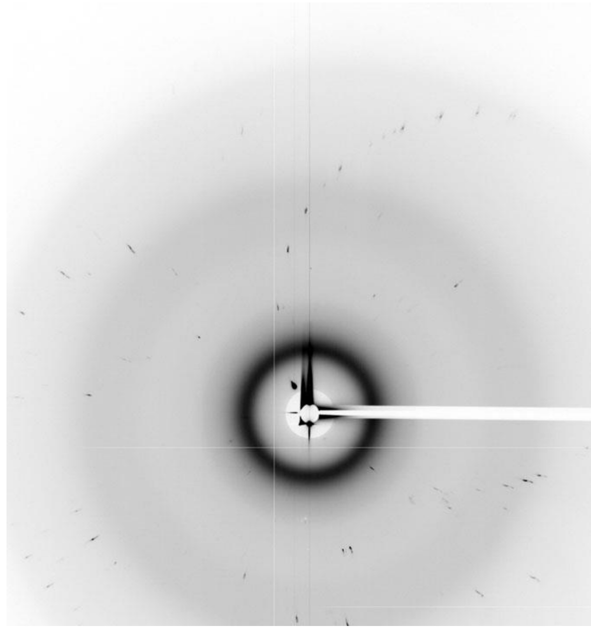

Fig. 2. Obtained XRD pattern of the cordierite-like phase in Al-rich chondrule in Y-82094. This image is a composite photograph of 251 exposure shots. Because of energy scanning from 20 to 30 keV, the diffraction spots show streaks.

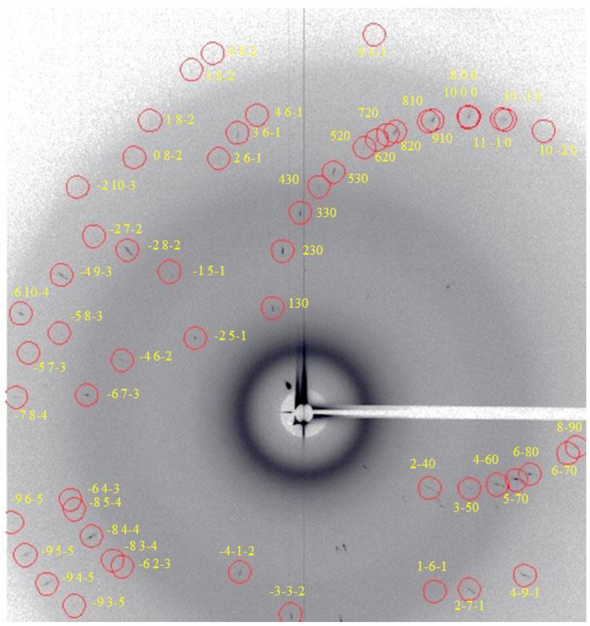

Fig. 3. XRD pattern of the cordierite-like phase in Al-rich chondrule in Y-82094 with indices (yellow numbers next to red circles) using the indialite crystal structure. Successful indexing by the indialite structure reveals that this phase is indialite rather than cordierite.