26Al IN CHONDRULES FROM CR CARBONACEOUS CHONDRITES. K. Nagashima1, A. N. Krot1, and G. R. Huss1,2 Hawaii Institute of Geophysics and Planetology, University of Hawai`i at Manoa, 1680 East-West Road, Honolulu, HI 96822, USA. (kazu@higp.hawaii.edu)

Introduction: The short half-life (0.72 Myr) and the inferred uniform distribution of 26Al in the inner Solar System [1, 2] makes it one of the best chronometers for dating the earliest processes in the solar nebula, including CAI- and chondrule formation. The 26Al-26Mg systematics in chondrules from primitive ordinary (UOC3.0-3.1) and CO3.0 chondrites suggest contemporaneous formation of chondrules from these meteorite groups that started ~1 Myr after formation of CAIs with initial 26Al/27Al ratio [(26Al/27Al)0] of ~5×10^-5 and lasted for ~2 Myr [3-10]. In contrast, (26Al/27Al)0 of three CR chondrules range from 1×10^-6 to 6×10^-6, corresponding to an age difference of ~2-4 Myr after CAIs [11]. CR chondrites are among the most primitive meteorites in our collections and appear to have avoided thermal metamorphism which potentially disturbed the Al-Mg system. The Al-Mg system in CR chondrules probably has recorded their crystallization ages. The Al-Mg ages of CR chondrules are consistent with their young 207Pb-206Pb ages [12]. In an attempt to further constraining the age and duration of chondrule formation in the early solar system, we extended our study of 26Al-26Mg systematics of CR chondrules.

Samples and Analytical Techniques: Mg-isotopic compositions were measured in four Al-rich and two Type I chondrules (Fig. 1) from El Djouf 001 and Acfer 311 CR chondrites using the University of Hawai`i Cameca ims-1280 SIMS. A 100–250 pA O⁻ primary ion beam was focused to ~5-7 µm. The secondary ion mass spectrometer was operated at +10 keV with a 50 eV energy window. Mg isotopes and 27Al were measured with monocollector EM and FC, respectively. The mass-resolving power was set to ~3800, sufficient to separate interfering hydrides and doubly charged 48Ca⁺. 26Mg⁺ was calculated assuming a linear mass-fractionation law. Note that, with the small degree of instrumental and intrinsic mass fractionation for these measurements and the relatively large isotopic effects, the choice of fractionation law makes no substantive difference in the results. Relative sensitivity factor for plagioclase was calculated based on the measurements on Miyakejima plagioclase standard.

Results and Discussion: The Mg isotopic data from plagioclase grains from 6 magnesium-rich
chondrules are plotted on Al-Mg isochron diagrams in Fig. 2. Al/Mg ratios in plagioclase range from 40 to 160. Apparent $^{26}\text{Mg}/^{24}\text{Mg}$ excesses are resolved at the 2σ level in 3 out of 6 chondrules suggesting that live $^{26}\text{Al}$ existed at the time these chondrule melts crystallized. Model Al-Mg isochrons (fitted lines are forced through the origin) yield estimates for $(^{26}\text{Al}/^{27}\text{Al})_0$ of $(4.5±1.1)\times10^{-6}$ for ED1-MKCHD1, $(3.2±1.3)\times10^{-6}$ for ED1-PL72CHD5, and $(3.2±1.4)\times10^{-6}$ for A311-PL20CHD2. The remaining chondrules have no resolvable $^{26}\text{Mg}^*$ and only upper limits of $(^{26}\text{Al}/^{27}\text{Al})_0 <3\times10^{-6}$ are indicated for analyses of ED1-MKCHD9, ED1-PL72CHD1, and ED1-PL72CHD7.

The inferred $(^{26}\text{Al}/^{27}\text{Al})_0$ in the CR chondrules are summarized in Fig. 3. The $(^{26}\text{Al}/^{27}\text{Al})_0$ in CO3.0-3.1 [3-7] and CO3.0 [8-10] are also shown. In UOC3.0-3.1 chondrules, $(^{26}\text{Al}/^{27}\text{Al})_0$ range from $-0.4\times10^{-5}$ to $2.3\times10^{-5}$ ($-0.9\times10^{-5}$ in average). In CO3.0 chondrules, $(^{26}\text{Al}/^{27}\text{Al})_0$ range from $-0.2\times10^{-5}$ to $1.4\times10^{-5}$ ($-0.8\times10^{-5}$ in average). No systematic differences were found between UOC3.0-3.1 and CO3.0 chondrules. In contrast, most CR chondrules have lower initial $(^{26}\text{Al}/^{27}\text{Al})_0$ ($0.1-0.4)\times10^{-5}$. The average of $(^{26}\text{Al}/^{27}\text{Al})_0$ calculated from 6 chondrules having resolvable $^{26}\text{Mg}^*$ is $0.3\times10^{-5}$, significantly lower than those in UOC3.0-3.1 and CO3.0.

Figure 3 shows relative age differences between CAIs with the canonical $^{26}\text{Al}/^{27}\text{Al}$ ratio and chondrules in UOC3.0-3.1, CO and CR chondrites. Relative ages of UOC3.0-3.1 and CO3.0 chondrules are ~1-3 Myr inferred from their $^{26}\text{Al}/^{27}\text{Al}$. On the other hand, CR chondrules have ages of 2-4 Myr inferred from their $^{26}\text{Al}/^{27}\text{Al}$. The majority of CR chondrules give younger ages than the majority of UOC and CO chondrules, which could imply formation of most CR chondrules postdated the formation of most OC and CO chondrules. The range of relative ages of CR chondrules is consistent with an age difference (2.5±0.9) Myr between CV CAIs and CR chondrules inferred from $^{207}\text{Pb}/^{206}\text{Pb}$ isotope systematics [12]. However, most of the Al-Mg ages in CR chondrules fall at the younger end of that range (>3 Myr after CAIs) and appear to be systematically younger than those inferred from $^{207}\text{Pb}/^{206}\text{Pb}$ system (Fig. 3). This could indicate either that the absolute ages of CV CAIs are older, or absolute ages of CR chondrules are younger than inferred from the $^{207}\text{Pb}/^{206}\text{Pb}$ system.