FINE-GRAINED METAL IN SIERRA GORDA 054 (L4 CHONDRITE)

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Introduction

Fe,Ni- metal is a typical component of the ordinary chondrites (OC). It usually occurs as mm-sub-mm grains comprised by an assemblage of a low-Ni metal phase ("kamacite") and taenite (fine-grain metal particles, FGM) (Fig.1). Local shock melting of FGM and surrounding host material forms melt pockets (MP). They usually occur in moderately shocked OC [1, 2]. The shock-melted assemblages of Fe Ni- metal and troilite often have dendritic and cellular structure resulted from rapid crystallization of the shock melt [4-6]. Here we report data of SEM and EPMA investigations of FGMs different in composition and degree of shock and thermal metamorphism in the Sierra Gorda 054 (SG 054) meteorite.

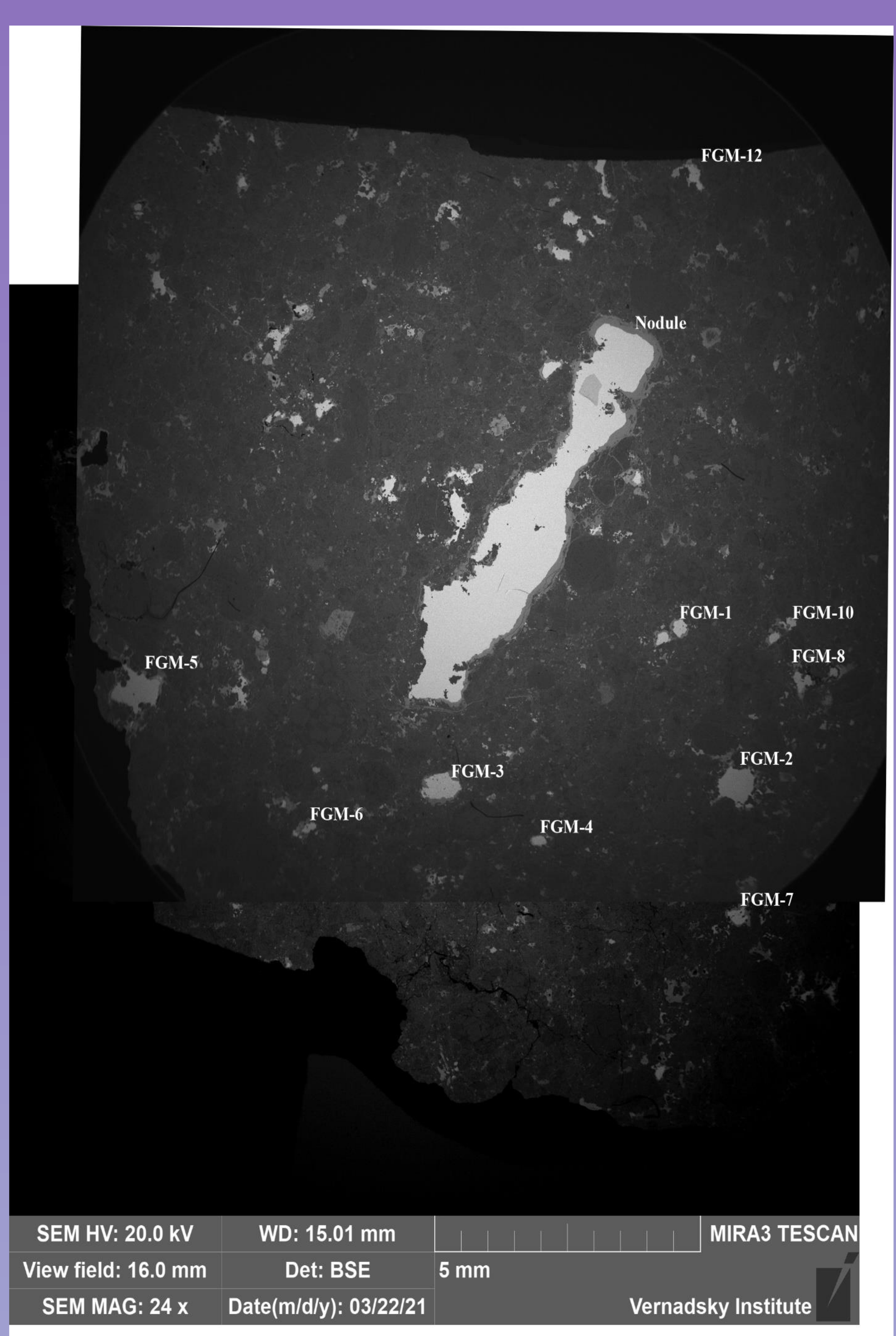

Fig. 1. Fine-grain metal particles (FGM).

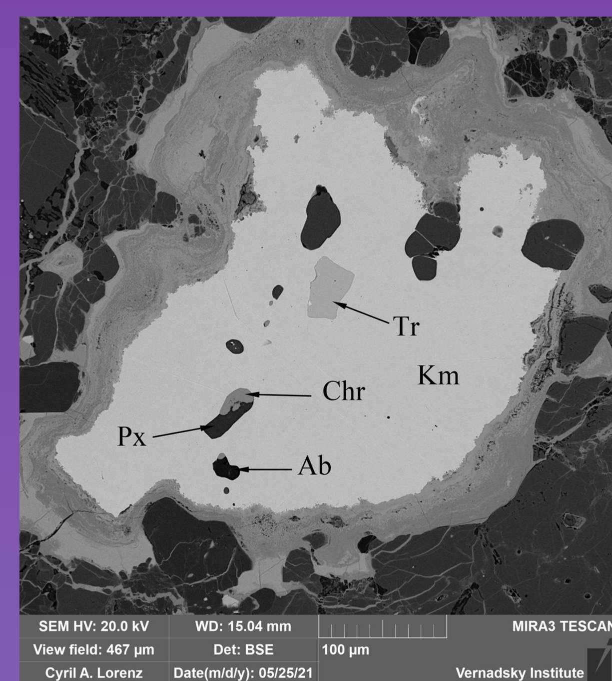

Fig. 2. BSE image of the T2 FGM.

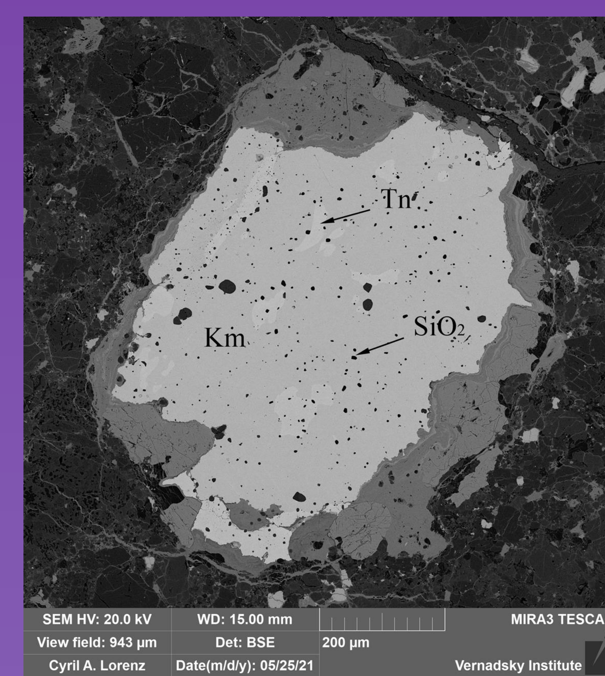

Fig. 3. BSE image of the T2 FGM.

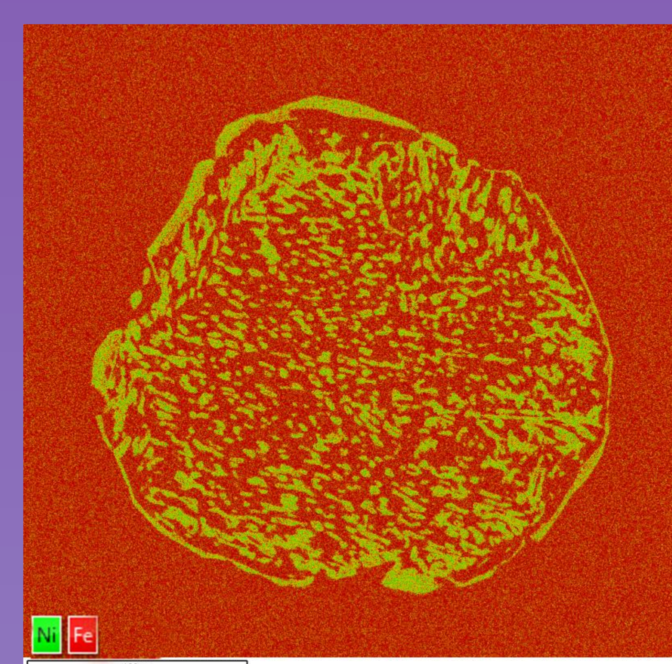

Fig. 4. X-ray map of the T3 FGM.

Results

Three types of FGMs were found in SG 054. Type 1 (T1) FGMs compose of kamacite (Km, 6.5-7 wt.% of Ni) with minor taenite (Tn) (~30 wt.% of Ni). Type 2 FGMs contain kamacite and are embedded in the silicate inclusions (SI), occasionally occurred in other types of FGMs. The inclusions typically compose of olivine, pyroxene, feldspar glass or aggregates of these minerals (Fig. 2) but one T2 FGM composes mostly of SiO_2 inclusions (Fig. 3). Type 3 (T3) FGMs (Fig. 4) consists of taenite (Ni ~36 wt.%) with rounded or irregular areas of tetrataenite (Tt, Ni 54-56 wt.%) - kamacite (Ni 3-3.5 wt.%) intergrowths. The intergrowths have fine cellular texture (Fig. 4). Tetrataenite also forms rims on the contact of Km and Tn. Bulk Ni content of Tt-Km areas is 20.5 wt.%. Rare prismatic grains of metal copper of 1-0.5 µm in size found in FGM#8 on the contacts of the Tt grains are unusually enriched in Au, Pd and Sn. Average composition acquired from the areas of ~1.5-2 µm in diameter with the copper grains in the center at 30 kV accelerating voltage by EDS SEM microanalysis indicates ~1.5 wt.% Au, ~1 wt.% Pd and 0.7 wt.% Sn (Fig. 5, 6ab).

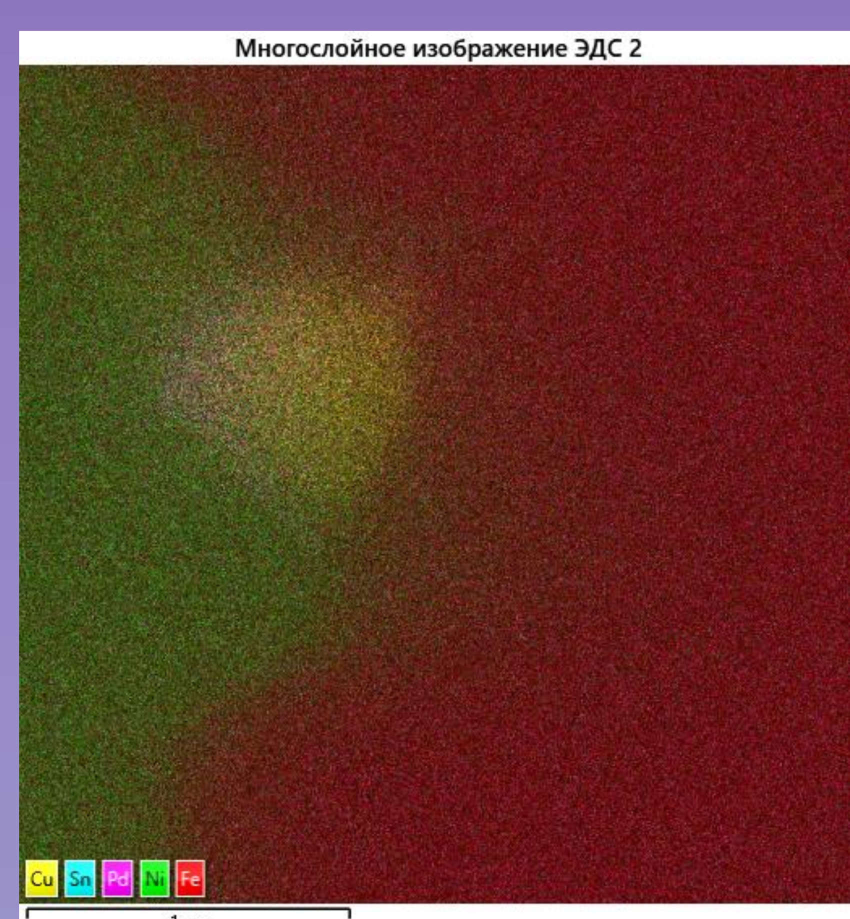

Fig. 5. X-ray map of the T3 FGM.

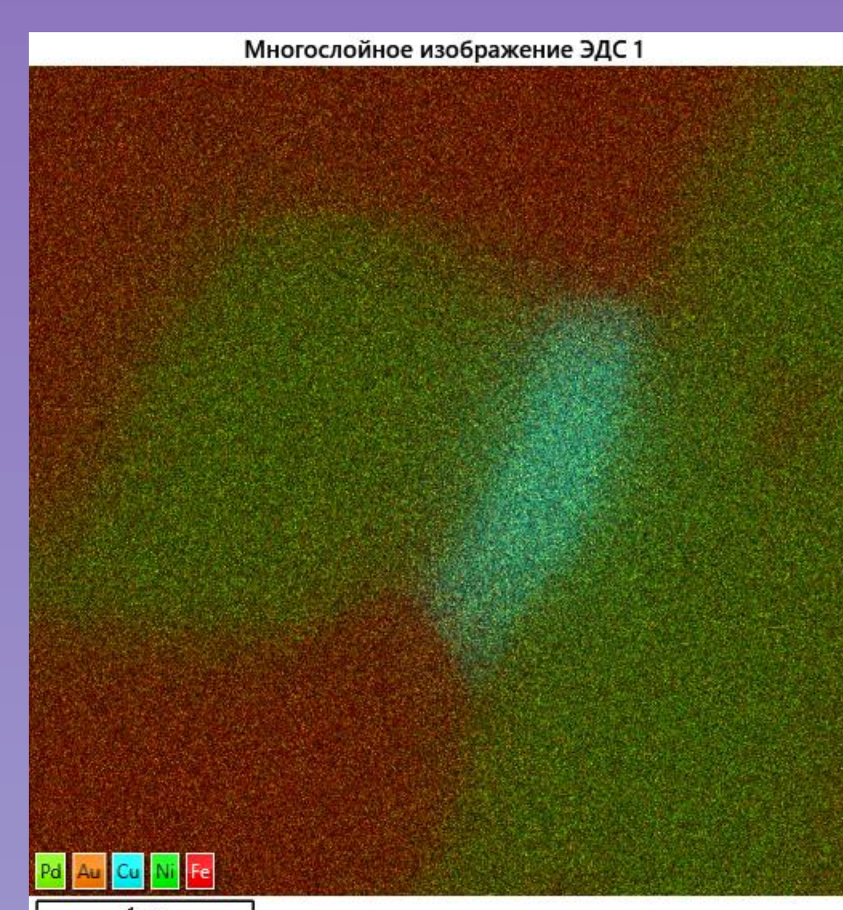

Fig. 6a. X-ray map of the T3 FGM.

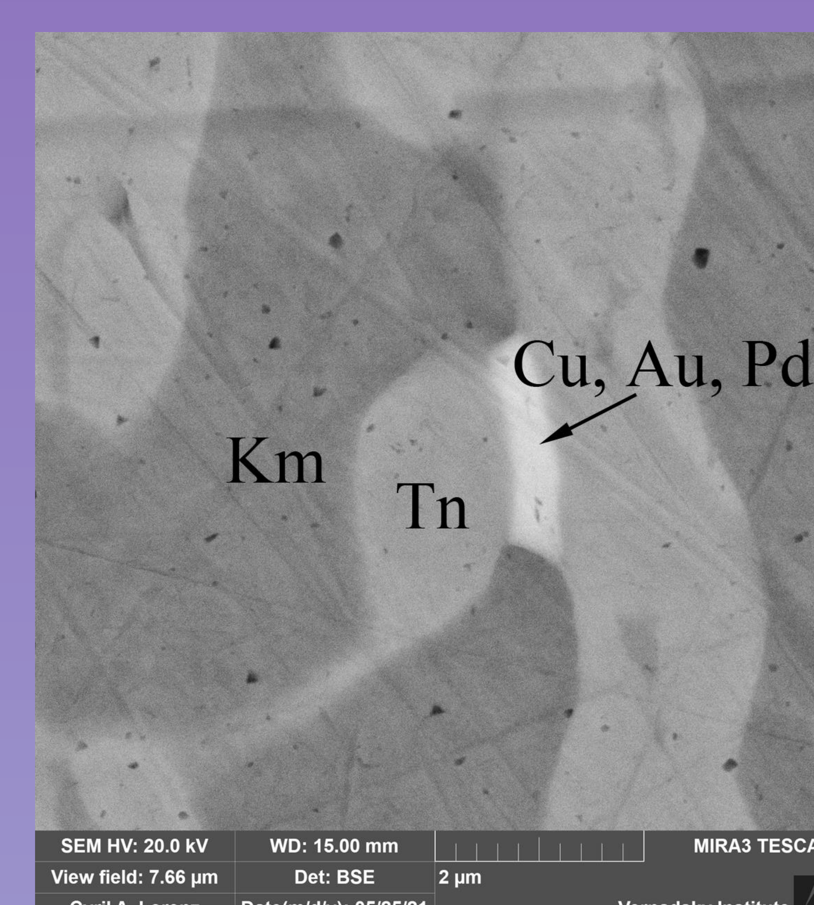

Fig. 6b. BSE image of the T3 FGM

Discussion. The T1 and T2 FGMs represent the typical ordinary chondrite metal. The silica-bearing FGM of T2 is unusual. Silica is a rare accessory mineral in OC [7] and could be enclosed in the FGM during shock destruction of the silica-bearing chondrule and metal melting. But, the identical size and habit of the silica grains could indicate an alternative mechanism: the FGM could be formed in the reduced nebular region (~fO_2 -20) [7] and contained Si dissolved in metal. The FGM was transported to the L-chondrite accretion region and shock melted, and Si was oxidized to SiO_2. The T3 FGMs are different from the typical FGMs of OCs. Cellular texture and abundance of SIs indicate their shock-melt origin. The T3 FGMs possibly were formed by a rapid crystallization of taenite due to quenching of shock-melted Ni-rich particle. Coexisting of Tt and Ni-poor Km indicates slow decomposition of the Fe-Ni solid solution below 400°C [8]. Irregular distribution of the Tt-Km aggregates in the host T3 FGMs could be a record of only partial melt of the source metal. The melt pockets begin to form under shock pressure ~15 GPa [2]. However, the shock stage of SG054 is S1 (P<5 GPa) and therefore T3 FGMs most likely were shocked in a different location and mixed with the host chondrite before lithification. The metal copper is an accessory phase of OCs [9] and could be formed from the Fe-Ni solid solution breakdown [10]. The Cu inclusions in the T3 FGM#8 obviously were formed due to diffusion, however, their composition points to the unusual metal source. FGM#8 enriched in intermediate- (Pd, Au, Cu) and highly volatile (Sn) elements could be formed from the medium-temperature nebular metal vapor and seems to be complementary to refractory metal inclusions in carbonaceous chondrites enriched in Os, Ir, Rh [11] and could be the most primitive metal of the OCs. The metal Cu in FGM#8 is a first mineral phase with macro-concentrations of Au, Pd and Sn found in the extraterrestrial material.

References: [1] Scott E. R. D. et al. (1982) Geochimica et Cosmochimica Acta 46:813-823. [2] Stöffler et al. (1991) Geochimica et Cosmochimica Acta 55:3845-3868. [3] Buchwald V. F. et al. (1966) Acta Polytechnica Scandinavica 51:1-45. [4] Bevan A. W. R. et al. (1979) Mineralogical Magazin 43:149-54. [5] Buchwald V. F., Clarke Jr. (1987) Meteoritics 22:121-135. [6] Olsen E. et al. (1994) Meteoritics 29:200-213. [7] Mittlefehldt D., et al. (1998) In Planetary Materials [8] Yang et al (1996) Journal of Phase Equilibria 17:522-531. [9] Rubin A. (1994) Meteoritics 29:93-98. [10] Tomkins A. (2009) Meteoritics & Planetary Science 44:1133–1149. [11] Daly L. et al. (2017) Geochimica et Cosmochimica Acta 216:61- 81.