Mackinawite $(Fe, Ni)_{1+x}S$ (x = 0 to 0.11)

Crystal Data: Tetragonal. *Point Group:* $4/m\ 2/m\ 2/m$. As well-formed thin tabular crystals, to 1 mm; massive, fine-feathery.

Physical Properties: *Cleavage:* Very good on {001}. Hardness = Soft. VHN = 63–89 (15 g load). D(meas.) = n.d. D(calc.) = 4.30

Optical Properties: Opaque. *Color:* Bronzy. *Streak:* Black. *Luster:* Metallic. *Pleochroism:* Strong. *Anisotropism:* Extreme.
R_1–R_2: (400) 17.7–25.7, (420) 17.0–28.0, (440) 16.4–30.2, (460) 16.2–32.2, (480) 16.1–34.4, (500) 16.0–36.5, (520) 16.1–38.4, (540) 16.1–40.0, (560) 16.3–41.4, (580) 16.5–42.5, (600) 16.7–43.3, (620) 17.0–43.9, (640) 17.2–44.3, (660) 17.4–44.5, (680) 17.5–44.6, (700) 17.7–44.6

Cell Data: *Space Group:* $P4/nmm$. $a = 3.6735(4)$ $c = 5.0328(7)$ $Z = 2$

X-ray Powder Pattern: Mackinaw mine, Washington, USA.
5.03 (100), 2.31 (90), 1.809 (80), 2.96 (70), 1.838 (50), 1.729 (50), 1.055 (40)

Chemistry:	(1)	(2)	(3)		(1)	(2)	(3)
Fe	63.0	58.8	54.9	Ni	3.1	3.8	8.8
Cu		2.0	0.1	S	34.0	35.9	35.8
Co			0.4	Total	100.1	100.5	100.0

(1) Mackinaw mine, Washington, USA; by electron microprobe, corresponding to $(Fe_{1.06}Ni_{0.05})_{\Sigma=1.11}S_{1.00}$. (2) Talnakh area, Russia; by electron microprobe, corresponding to $(Fe_{0.94}Ni_{0.06}Cu_{0.03})_{\Sigma=1.03}S_{1.00}$. (3) Scotia deposit, Australia; by electron microprobe, corresponding to $(Fe_{0.88}Ni_{0.13}Co_{0.01})_{\Sigma=1.02}S_{1.00}$.

Occurrence: Formed by hydrothermal activity in mineral deposits, during serpentinization of peridotites, and in the reducing environment of river bottom muds; may be produced by magnetotactic and sulfate-reducing bacteria. Rarely in iron and carbonaceous chondrite meteorites.

Association: Chalcopyrite, cubanite, pentlandite, pyrrhotite, greigite, maucherite, troilite.

Distribution: Now known from a number of localities in addition to those listed here. In the USA, at the Mackinaw mine, Snohomish Co., Washington [TL]; in muds from the bottom of the Mystic River, Boston, Suffolk Co., Massachusetts; from the Howard Montgomery quarry, Howard Co., Maryland; in California, from the Kramer borate deposit, Boron, Kern Co. In Canada, in the Muskox intrusion, Northwest Territories, and at the Falconbridge mine, Sudbury, Ontario. From the Outokumpu mine and Hitura, Finland. At the Vena mines, near Askersund, Örebro, Sweden. In the Fiat mine, Piedmont, Italy. At Landsberg, near Obermoschel, Rhineland-Palatinate, Germany. From England, at The Rill, Kynance Cliff, The Lizard, Cornwall. On Cyprus, at Skouriotissa. In the Talnakh area, Noril'sk region, western Siberia, and at the Kovdor massif, Kola Peninsula, Russia. From Broken Hill, New South Wales, and the Scotia nickel deposit, Kalgoorlie, Western Australia.

Name: For the Mackinaw mine in Washington, USA.

Type Material: n.d.

References: (1) Evans, H.T., Jr., C. Milton, E.C.T. Chao, I. Adler, C. Mead, B. Ingram, and R.A. Berner (1964) Valleriite and the new iron sulfide, mackinawite. U.S. Geol. Sur. Prof. Paper 475-D, D64–D69. (2) (1964) Amer. Mineral., 49, 1497 (abs. ref. 1). (3) Kouvo, O. and Y. Vuorelainen (1963) A tetragonal iron sulfide. Amer. Mineral., 48, 511–524. (4) Buchwald, V.F. (1977) The mineralogy of iron meteorites. Phil. Trans. Royal Soc. London, A. 286, 453–491. (5) Ostwald, J. (1978) A note on the occurrences of nickeliferous and cupriferous mackinawite. Mineral. Mag., 42, 516–517. (6) Lennie, A.R., S.A.T. Redfern, P.F. Schofield, and D.J. Vaughan (1995) Synthesis and Rietveld crystal structure refinement of mackinawite, tetragonal FeS. Mineral. Mag., 59, 677–683. (7) Ramdohr, P. (1969) The ore minerals and their intergrowths, (3rd edition), 673–679. (8) Criddle, A.J. and C.J. Stanley, Eds. (1993) Quantitative data file for ore minerals, 3rd ed. Chapman & Hall, London, 335.