(*11*) in polymeric material, since polymers consist of long-chain organic molecules. Therefore, the presence or absence of tracks in plastic adjacent to biological matter (for example, the Apollo helmets) should correlate directly with the presence or absence of damage caused by heavy particles in living cells (*10*).

Comparison of the curvatures of the track sides reveals that the particle whose track is illustrated in Fig. 3 came from outside the helmet (since looking along the track reveals that the cone angle decreases toward the base) whereas, by contrast, the ion corresponding to the track in Fig. 1C came from within the helmet (cone angle increasing toward the base). Thus, three of the tracks shown in Fig. 1, C, D, and A, represent particles that penetrated through the helmet and came to rest in the opposite side on their way out.

In order for the replica technique to be useful it must faithfully reproduce the shape and dimensions of the etched track. On the basis of an intercomparison of etched tracks with their replicas, it is clear that the replica does reproduce the dimensions down to submicrometer sizes but that (perhaps due to surface charges) the shapes of slender tracks < 2 μm in diameter are often bent. Figure 4B shows a tapering track due to a particle that nearly crossed a sheet of Lexan polycarbonate, as sketched in Fig. 4A. A replica was made (as diagrammed in Fig. 4A), gold-coated by evaporation, and photographed. In Fig. 4B the photographs of the replica are compared with those taken directly of the Lexan. Fine detail is reproduced on a micrometer scale. In cellulose nitrate we have successfully replicated conical tracks with lengths up to 18 μm and bases 0.4 to 0.5 μm in diameter.

The replicating procedure makes possible the use of opaque or optically anisotropic plastic sheets as identifiers of particle tracks. Meaningful direct optical measurements of track dimensions are difficult in such materials, for example, Cronar, Melinex, and Mylar; the use of a replica allows accurate measurements to be made (*12*).

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8a. Although in principle different varieties of Lexan may have different sensitivities, we find that this is not the case here. Samples of helmet Lexan (9040-112) and of the previously calibrated (*5*) Lexan (8070–112) gave identical etching response to Ne^{20} and S^{32} ions from the Yale Heavy Ion Accelerator. The two irradiations were performed at a pressure of 160 mm of oxygen to simulate conditions at the inside of the space helmets during the Apollo missions.

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12. Even in Lexan, which is an optically more uniform material than the plastics named above, discrepancies exist between measurements on individual tracks when viewed through the material with the track pointing down as compared with the case when the track is pointing up, and one views through the whole sheet thickness (*7*). Our measurements suggest that the down-pointing position gives numbers that are closer to the true values.
13. We acknowledge helpful conversations with C. P. Bean, J. A. Bergeron, and V. P. Bond. Work supported in part by NASA contract NAS-9-9828.

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Cubic FeS, a Metastable Iron Sulfide

Abstract. *Studies of the corrosion products of metallic iron formed in the absence of air oxidation in solutions of hydrogen sulfide have revealed the existence of a new phase, cubic FeS, associated with tetragonal iron sulfide,* $Fe_{1+x}S$. *This new phase is metastable and has a sphalerite-like structure.*

The initial corrosion product of metallic iron in aqueous solutions of H_2S is tetragonal $Fe_{1+x}S$ (mackinawite). Hexagonal FeS (troilite) appears after a few days at room temperature, or after a few hours at elevated temperature. Finally, cubic FeS_2 (pyrite) is formed, if an oxidizing agent is present (*1, 2*).

In experiments of the same type, I observed the formation of a metastable phase, cubic FeS (*3*). This iron sulfide forms on reagent-grade metallic iron, in 2 or 3 days at room temperature, if the initial concentration of H_2S is greater than 0.01*M* and the *p*H is between 4.0 and 4.5. The presence of air or foreign ions (chloride, sulfate) must be avoided.

The x-ray diffraction powder pattern (Table 1) must be taken rapidly, since cubic FeS is metastable when it is not in contact with the solution: the intensity of the reflections decreases by about 10 percent per hour. The *d* values and relative intensities are very similar to those of cubic ZnS (sphalerite). The cubic cell parameter, extrapolated against the Nelson and Riley function, is $a_0 = 5.423 \pm 0.001$ Å at 25°C. A very similar value, $a_0 = 5.4246 \pm 0.0006$ Å, is deduced from the variation of the cell parameter of the solid solution (Zn,Fe)S (*4*). The good agreement between observed and calculated intensities confirms the sphalerite-like structure of cubic FeS.

A comparison of the crystal structures of tetragonal and cubic FeS shows that the formation of the metastable cubic form is favored by epitaxial growth at the interface between the tetragonal iron sulfide and the hydrogen sulfide solution.

Tetragonal $Fe_{1+x}S$ has an anti-PbO

Table 1. X-ray diffraction powder data for cubic FeS (Ni-filtered CuKα radiation). *d*, Interplanar spacing; I/I_0, intensity of a given set of planes relative to the strongest intensity.

hkl	d_{obs} (Å)	d_{calc} (Å)*	$(I/I_0)_{obs}$	$(I/I_0)_{calc}$†
111	3.127	3.131	100	100
200	2.705	2.712	6	5.5
220	1.914	1.917	54	56.9
311	1.634	1.635	36	32.8
222	1.563	1.565	< 5‡	1.1
400	1.354	1.356	8	7.2
331	1.243	1.244	< 14‡	10.5
420	1.212	1.213	< 2	0.8
422	1.106	1.107	10	12.8
511–333	1.044	1.044	3	7.3
440	0.9581	0.9587	3	4.4
531	0.9161	0.9167	9	8.6
620	0.8570	0.8575	7	8.7

* Calculated with the extrapolated value of $a_0 =$ 5.423 Å. † Calculated with *B* (isotropic temperature factor) = 1.0 Å². ‡ Two reflections of $Fe_{1+x}S$ interfere: 211 with 222 (cubic) and 203 with 331 (cubic).

type of structure (*1*), in which the sulfur atoms approximate the face-centered cubic packing: $a' = a\sqrt{2} = 5.197$ Å $\approx c = 5.035$ Å. The iron atoms, which occupy layers of adjacent tetrahedral holes at distances of 2.60 Å, make close contact with one another as well as with sulfur. The excess iron ($x = 0.05$ to 0.06) occupies the remaining unused tetrahedral holes randomly (*5*).

In cubic FeS the sulfur atoms are arranged on the nodes of a face-centered cubic lattice; one-half of the tetrahedral holes are occupied by the iron atoms. The lattice parameter is only 4.3 percent greater than the a' value of the tetragonal sulfide. Thus, the similarity in atomic arrangement and in lattice parameters facilitates the epitaxial nucleation and growth of cubic FeS.

Although hexagonal FeS is a more stable phase (*6*), it appears as a corrosion product long after cubic FeS, because its growth requires a reconstructive transformation of the tetragonal sulfide. There are some major differences between hexagonal FeS and the cubic and tetragonal structures: the iron atoms occupy all of the octahedral holes of the hexagonal closest packing of sulfur and form trigonal-prismatic clusters.

Interatomic distance $\mathrm{Fe(II)}_{\mathrm{tetrahedral}}$–S in cubic FeS, 2.348 Å, is in good agreement with the other known values: 2.36 Å in stannite, Cu_2FeSnS_4; 2.33 Å in $FeCr_2S_4$; 2.36 Å in $FeLu_2S_4$; and 2.38 Å in $FeYb_2S_4$ (*7*). According to Pauling (*8*), the tetrahedral covalent radius of sulfur is 1.04 Å; by subtraction of this value from the Fe–S distance, the value 1.31 Å for the tetrahedral covalent radius of iron(II) in sulfides is obtained.

It is clear that in the first structure determination the interatomic distance Fe–S in tetragonal $Fe_{1+x}S$ was not known with precision, because the sulfur coordinate z(S) was assumed to be 0.25 (*1*). On the basis of more precise intensity measurements and calculations, I found that $z(\mathrm{S}) = 0.28 \pm 0.01$ and $\mathrm{Fe{-}S} = 2.32 \pm 0.02$ Å. The covalent radii for this compound are 1.30 Å for iron (half the interatomic Fe–Fe distance) and 1.02 ± 0.02 Å for sulfur, in good agreement with the previously calculated values.

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Bottom Velocity Observations Directly under the Gulf Stream

Abstract. *Speeds as high as 44 centimeters per second were observed 200 meters above the ocean bottom under the Gulf Stream at 70°W longitude and were associated with time-dependent motion that had a speed range of 40 centimeters per second and a time scale of about 30 days. These deep current fluctuations appear to be coupled with fluctuations in the surface position of the Stream and with surface and bottom current fluctuations 200 kilometers to the north.*

Two-month records of the bottom velocity directly under the Gulf Stream have been obtained from current meters moored 35 km apart. The records are very similar and exhibit large speed variations; a fluctuation of 40 cm/sec occurred on a time scale of about 30 days. The mean velocity components were 2 and 10 cm/sec in the eastward and northward directions. Both near-surface and near-bottom currents from moorings located about 200 km north of the position of the Stream axis show variability somewhat similar to that observed near the bottom under the Gulf Stream, with amplitudes reduced by a factor of 2 to 5. A current meter record of short duration from a bottom mooring located under the inshore edge of the Stream showed a similar reduction in amplitude. Measurements were simultaneously obtained of the varying position of the surface Gulf Stream as inferred from the surface and near-surface temperature structure. A comparison of the surface and bottom variability is of great interest, although the physical interpretation of the speeds obtained from the movement of near-surface features is moot (see below), and the horizontal as well as vertical separation of the measurements must be kept in mind. The north-south variability in path and in near-bottom currents was essentially in the same direction at nearby times on similar time scales; the amplitudes of the speed fluctuations as inferred from variations in path position are at least a factor of 2 smaller than near-bottom speed amplitudes. The time-averaged orientation of the surface Stream path was almost due east; the near-bottom current directions were normally in the same quadrant as the orientation of the surface path, but with a time lag and with directions offshore (onshore) of the surface path for offshore (onshore) path orientation.

Observations of the path and structure of the Gulf Stream from 75° to 60°W were completed in May to July 1969 as a cooperative effort among several groups (at Harvard University, the Naval Oceanographic Office, the Naval Research Laboratory, and the Woods Hole Oceanographic Institution). This program of observations included measurements of the position of the surface temperature gradient (an indicator for the location of the Stream, hereafter denoted by ΔT_S) as determined by airborne radiation thermometry (20 flights); repetitive tracking (from the R.V. *Chain*) of the position of the 15°C isotherm at 200 m (the standard indicator for the Stream location, hereafter denoted T_{15}) between 71° and 69°W with a final track from 69° to 64° (in addition, a hydrographic section was taken and drogues were tracked); four current meters, one on