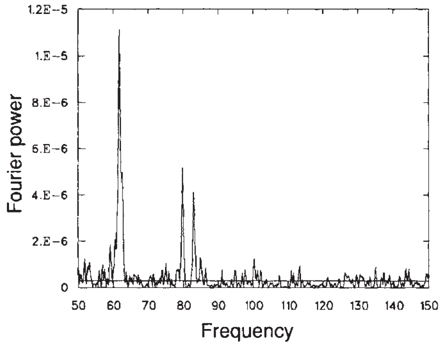
Muonium in fullerite

SIR — We wish to report the observation of muonium after implantation of positive muons into C_{60}/C_{70} fullerite[1]. Muonium (Mu; μ^+e^-) is a light analogue of the hydrogen atom, and has been used to provide information on defect centres in semiconductors[2-4] and radicals in organic compounds[5,6]. In graphite, only the 'bare' μ^+ signal is observed, whereas in diamond and other semiconductors two forms of muonium ('vacuum' Mu and 'anomalous' Mu*) occur[3,4]. We have found that at least 30 per cent of the muons implanted into fullerite form vacuum Mu and a muonated radical species.



Muon-spin-rotation spectrum of C_{60}/C_{70} fullerite at 210 K and an applied field of 58.4 Oe.

Our experiment, which used standard muon-spin-rotation/relaxation (μSR) techniques, was carried out at the TRIUMF cyclotron, Vancouver. The powder sample of fullerite (C_{60} with about 10 per cent C_{70}) was from MER Corp., Tucson, Arizona. We measured the amplitude and Larmor precession frequencies of μ^+ and Mu signals, over 4 μs after implantation of the muons (capture occurred in less than a nanosecond). The figure shows the main muonium lines obtained at 210 K in an applied field of 58.4 oersted (Oe). The doublet centred at 81.2 MHz is characteristic of vacuum Mu as its splitting corresponds to a μ^+–e^- hyperfine interaction of 4,265 MHz, slightly reduced by the medium from the 4,463 MHz for isolated muonium in vacuum[2-5]. Such muonium atoms are usually located in interstitial cavities in a variety of solids (including ice), and can be highly mobile. The stronger signal at 61.7 MHz was assigned to the formation of radicals on the surface. A partner signal at 264 MHz (not shown) implies that this radical has a hyperfine splitting of 325.7 MHz. The radical appears to be isotropic, but it is still to be determined whether this is intrinsic or due to rapid molecular rotation (that is, the radical signal is also a probe of rotational dynamics)[4,6]. The diamagnetic μ^+ signal at 0.791 MHz accounts for 60 per cent of the total amplitude. No other Mu signals were observed above the 2×10^{-6} level up to 300 MHz. These assignments were confirmed by spectra at two other values of applied field.

The vacuum Mu species might reside inside the C_{60} cages, and/or be almost free at or near the surface of the molecules, where it might react to form the observed radical. It will be interesting to see whether this Mu can be released into the vacuum, as is the case for very fine silica powders[2]. If ^{13}C is substituted into the fullerene molecules, the muonated radical signal could be used to probe the electron spin density and coupling constants in the carbon rings. As in silica [7-9], Mu could react with and provide information about other molecules adsorbed on the molecular surfaces, and so give insight into the possible catalytic properties of fullerite.

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Imprints on DNA fingerprints

SIR — Each autoradiogram in the DNA population databases maintained by the FBI contains a replication of one set of bands from a constant, known, human DNA sample. Comparing the band-length estimates of this control sample made by five laboratory technicians, I found there were statistically significant differences between mean estimates and statistically significant correlations between estimates of the two alleles comprising a pair of bands. These findings have serious implications for forensic DNA fingerprinting.

FBI population databases are separated racially, but the control sample on each autoradiogram is always the same. Therefore, I ignored the database racial designations. The control sample produces two bands with three probes and one band with one probe. The results are shown in the table.

Technician G.S.R's estimated band lengths are statistically significantly smaller than those of A.M.G. and L.A.W. Furthermore, the mean band-length estimates by G.S.R. are smaller than those by the other four technicians in 25 of the 28 possible comparisons with G.S.R. Also, H.L.L. estimates the length of the D17S79 band to be statistically significantly larger than do each of the other four technicians.

It can also be seen in the table that the length estimates of a pair of bands are correlated with each other for each of the technicians. Additionally, partial correlation coefficients of band 1 and band 2 length estimates were calculated for each probe by controlling for technicians, and also for each technician by

PROBE	OBSERVER	NO. OBS	BAND 1		BAND 2		COVARIANCE	CORR. COEF. r	PROBABILITY
			MEAN	STD.D.	MEAN	STD.D.			
D4 S139	GSR	27	9070.63	85.46	7633.67	50.14	2495.22	.5824	.001
	AMG	109	9117.57	91.64	7682.33	69.64	4353.18	.6819	.000
	LAW	25	9136.12	86.28	7689.88	67.86	3475.18	.5935	.002
	HLL	10	9130.50	51.01	7654.50	52.51	1655.72	.6181	.057
	MEC	24	9077.92	118.59	7707.42	96.72	4030.73	.3514	.092
D1 S7	GSR	28	12538.75	165.42	9209.82	71.82	6685.44	.5628	.002
	AMG	115	12891.77	272.24	9275.98	90.51	12440.86	.5049	.000
	LAW	17	12716.18	235.06	9252.88	74.46	9308.40	.5318	.028
	HLL	8	12537.38	197.17	9226.00	89.51	16622.14	.9418	.000
	MEC	17	12904.41	326.99	9264.53	100.40	21563.96	.6568	.004
D2 S44	GSR	30	3761.23	20.20	2915.20	15.95	95.33	.2960	.112
	AMG	103	3777.87	22.16	2925.08	15.08	181.78	.5440	.000
	LAW	59	3772.69	23.24	2924.49	16.91	244.08	.6209	.000
	HLL	11	3762.00	18.94	2922.73	11.73	58.30	.2623	.436
	MEC	24	3769.12	27.72	2918.50	15.57	309.07	.7162	.000
D17 S79	GSR	23	1358.22	12.22					
	AMG	114	1360.26	12.51					
	LAW	62	1363.23	10.39					
	HLL	10	1370.60	7.97					
	MEC	20	1356.30	11.98					

Results of the analysis of band-length estimates from the control lanes on the autoradiograms from which the FBI population databases are constructed, separated by the four probes with which data were generated. The probes are D4S139, D1S7, D2S44 and D17S79, respectively. The results are presented separately for each of the five technicians (observers). The number of observations denotes the number of control lanes in the databases for each technician with each probe. The mean and standard deviation of each band-length estimate are shown. The estimated band lengths are expressed in kilo basepair units. The covariance and the correlation coefficient (r) between the two bands in the control lane are shown, as well as the probability of obtaining that correlation coefficient by chance if the band length estimates were unrelated to each other. Probe D17S79 generates only one detectable band.