between the average penetration rates in water and the different alcohols. Such was not the case when we measured the performance over the much shorter distance of 26 mm. We therefore suggest that this observation may help in explaining some of the conflicting results already published, namely that in cases where measurements of performance are made over a significant fraction of the bit life, differences in average rate of penetration are likely to be found, but they can just as well be attributed to a change in the rate of wear of the bit as to any hardening or softening of the rock being drilled.

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Q-band esr spectra of γ-irradiated Pyrex

Previous electron spin resonance (esr) work on γ-irradiated Pyrex at X-band (9.4 GHz) has revealed the well-known boron–oxygen hole centre (BOHC) spectrum and a narrow resonance at $g = 2.0008$ which has been ascribed to the E_1' electron centre [1] in sub-microscopic helices or chains of silica existing separately within the bulk borosilicate structure [2]. The narrow resonance was identified as the E_1' line by its lineshape, linewidth and g-value, and by the fact that it saturated easily with microwave power.

In an attempt to confirm this identification, the spectra were investigated at Q-band (35 GHz). Fig. 1 shows the first derivative signal obtained at liquid nitrogen temperature, 77 K, of a Pyrex sample having had a gamma dose of 8598 Mrad (85980 J g^{-1}). This spectrum has been numerically smoothed twice, according to the equation

$$A_H = \tfrac{1}{2}A'_H + \tfrac{1}{4}A'_{H+\Delta} + \tfrac{1}{4}A'_{H+\Delta}$$

where A_H is the amplitude of the plotted derivative curve at a magnetic field H, A'_H is the amplitude of the measured derivative curve at a magnetic field H, and Δ is the magnetic field increment, in this case 0.03 mT. A microwave power of 0.01 mW was used at a frequency of 34.91 GHz, and the derivative curve obtained in the usual way with 160 kHz modulation and phase-sensitive demodulation.

Fig. 1 has two main components, a broad line of width $\Delta H_{ms} \simeq 5$ mT and a narrow, complex resonance of overall width $\simeq 1.2$ mT. The broad line can be readily ascribed to the BOHC, which has been shown [3] to possess orthorhombic symmetry, while the lineshape over the central and high-field regions is produced by overlapping the four-line hyperfine components centred on

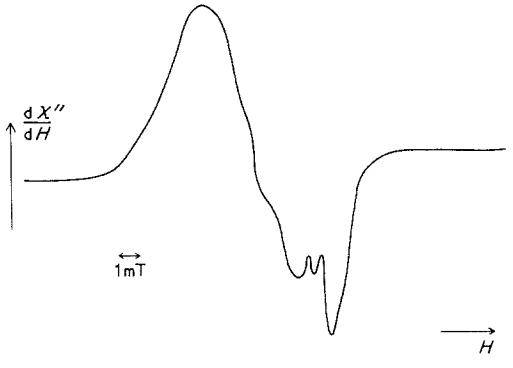

Figure 1 Q-band spectrum obtained from γ-irradiated Pyrex. Microwave power 0.01 mW, temperature 77 K.

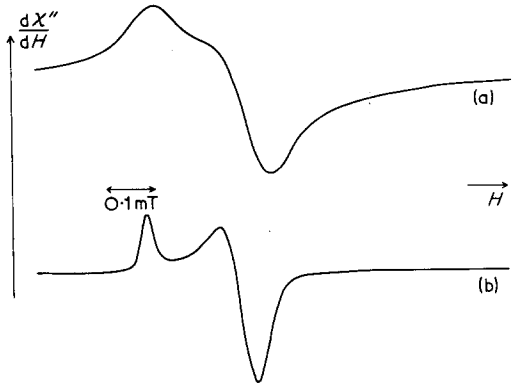

Figure 2(a) X-band spectrum of the E_1' centre in γ-irradiated Pyrex. Microwave power 0.05 mW, room temperature. (b) X-band spectrum of γ-irradiated silica. Microwave power 0.2 mW, room temperature.

g_1 and g_2 by standard "powder pattern" techniques. The four-line components arise from hyperfine interaction with the ^{11}B nucleus of spin 3/2. Knowing that the linewidth is principally hyperfine in origin explains why the line at Q-band is not much broader than the same line at X-band. The g-value of this BOHC line is estimated from Fig. 1 to be 2.01.

The narrow resonance bears an immediate resemblance to the well-known signal from silica glass at X-band. This signal is shown in Fig. 2(b), together with the narrow resonance from Pyrex as seen at X-band. These curves are reproduced from [2] for ease of comparison. It can be seen that the overall linewidth of the narrow component in Fig. 1 is four times greater than both that of the silica line and that of the corresponding Pyrex resonance at X-band. This dependence of linewidth on frequency shows that the asymmetry of the narrow spectrum must arise largely from g anisotropy. An estimate of g_{eff} for this component is 2.004. It is interesting to note the enhanced resolution afforded by the Q-band measurement by comparing Fig. 1 with Fig. 2a.

Similarity of g-values is not really sufficient evidence on which to base an identification, so two further tests were made. It has been shown [2, 4] that the BOHC signal saturates after a dose of between 50 and 100 Mrad, whereas the electron signal does not. In the first test a Pyrex sample, irradiated to 66 Mrad, was observed at Q-band and only the broad $g = 2.01$ resonance was seen. It is assumed here that the electron signal has been reduced below the detection limit of the spectrometer. In the second test an irradiated silica glass was observed, and the only visible signal was the complex narrow component at $g = 2.004$.

These tests show conclusively that the narrow resonance seen at X- and Q- bands in γ-irradiated Pyrex arises from the same electron trapping centre that is produced in γ-irradiated silica glass. The fact that the g-values of the hole and electron centres are not quite the same at the two measuring frequencies indicates that the Q-band energy levels are not linear extrapolations of the X-band energy levels. This is also borne out by the observation that the magnetic field separation of the two centres at Q-band is not four times as large as the separation at X-band. The contention is thus reinforced that the Pyrex E_1' centre arises from a sub-microscopic silica glass structure existing within the bulk borosilicate structure.

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