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Raman Microprobe Measurements of Stress in Ion Implanted Materials

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Raman microprobe measurements of ion implanted diamond and silicon have shown significant shifts in the Raman line due to stresses in the materials. The Raman line shifts to higher energy if the stress is compressive and to lower energy for tensile stress[1].

The silicon sample was implanted in a 60µm square with 2.56×10^{17} ions per square centimetre of 2 MeV Helium. This led to the formation of raised squares with the top 370 nm above the original surface. In Raman studies of silicon using visible light, the depth of penetration of the laser beam into the sample is much less than one micron. Thus, the Raman line is due to the silicon overlying the damage region.

A series of spectra were recorded at 5µm intervals across the raised square. The 520 cm^{-1} Raman line showed no broadening as would be expected if there were significant damage at the surface. The peak position shifted around 2.3 cm^{-1} to lower energy across most of the implanted region, relative to the unimplanted silicon, as shown in Figure 1. On the edges of the implanted region, the Raman line is shifted to higher energy by around 1.5 cm^{-1}. This indicates that the top of the raised area is under tensile stress, while the sides of the raised region are under compressive stress.

The diamond results are complicated by the transparency of the sample. The minimum depth resolution of the Raman microprobe is 2µm, and thus the Raman signal comes both from the diamond lying above the damage region, and the damage region itself, at about 1.7µm under the surface.

The diamond sample was a (110) diamond window which had been implanted with 2×10^{15}ions per square centimetre of 2.8 MeV carbon. One corner had been masked. Inspection of the edge between the implanted and unimplanted region showed the "notch" shown in Figure 2(a). Raman spectra were recorded at one micron intervals covering unimplanted-implanted-unimplanted-implanted. Both parallel and perpendicular polarisation components were collected.

The Raman spectrum of the bulk unimplanted sample showed a single sharp 1332 cm^{-1} line. All other spectra showed a similar sharp component, assigned to diamond above and below the damage region, and also a broad component, assigned to diamond at the depth of the damage region. The sharp component both in the bulk implanted material and in the region of the interface was shifted by around 1 cm^{-1} to lower energy, indicating a tensile stress.

The broad component varied widely in position, as shown in Figure 2(b). In particular, there was a very large shift to lower energy (around 6 cm^{-1}) for the spectrum from the centre of the enclosed "tongue" of implanted material. The graph shows that the implanted region close to the interface is under tensile stress, while the unimplanted region close to the interface is under compressive stress.

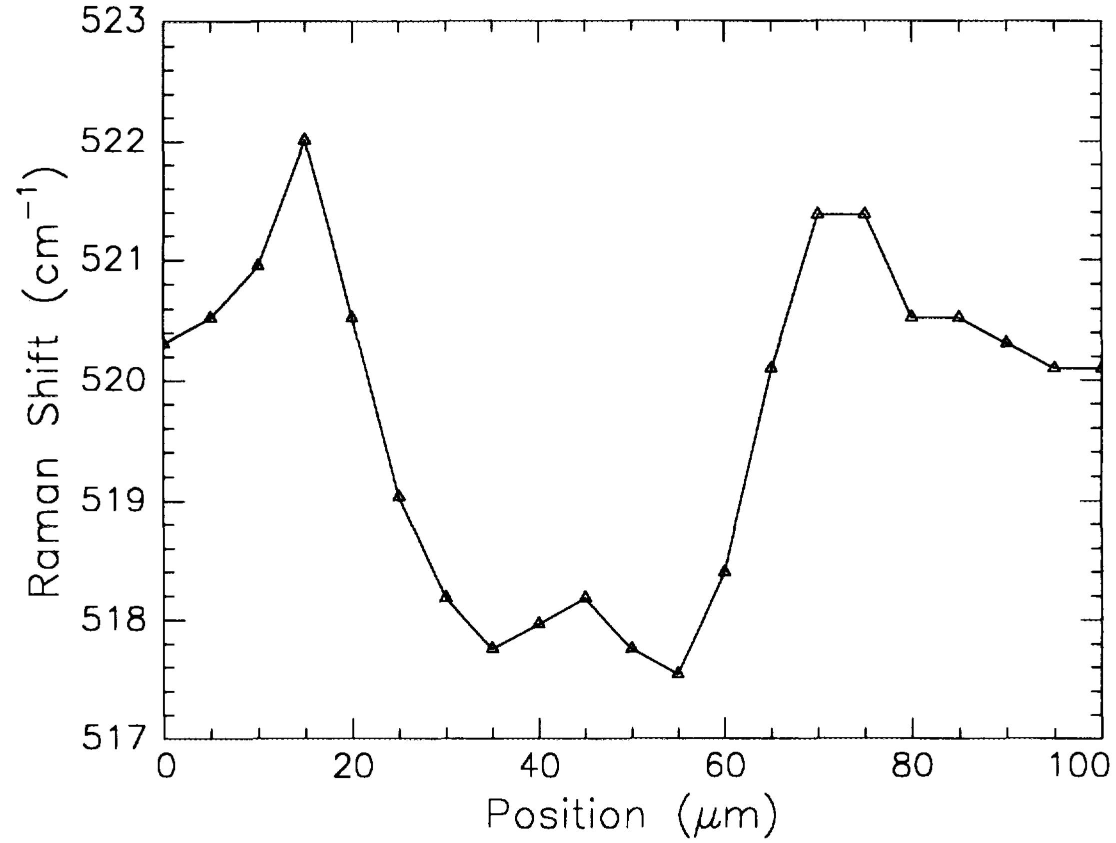

Figure 1. Variation of 520 cm^{-1} Raman line position across the raised implanted region of the silicon sample.

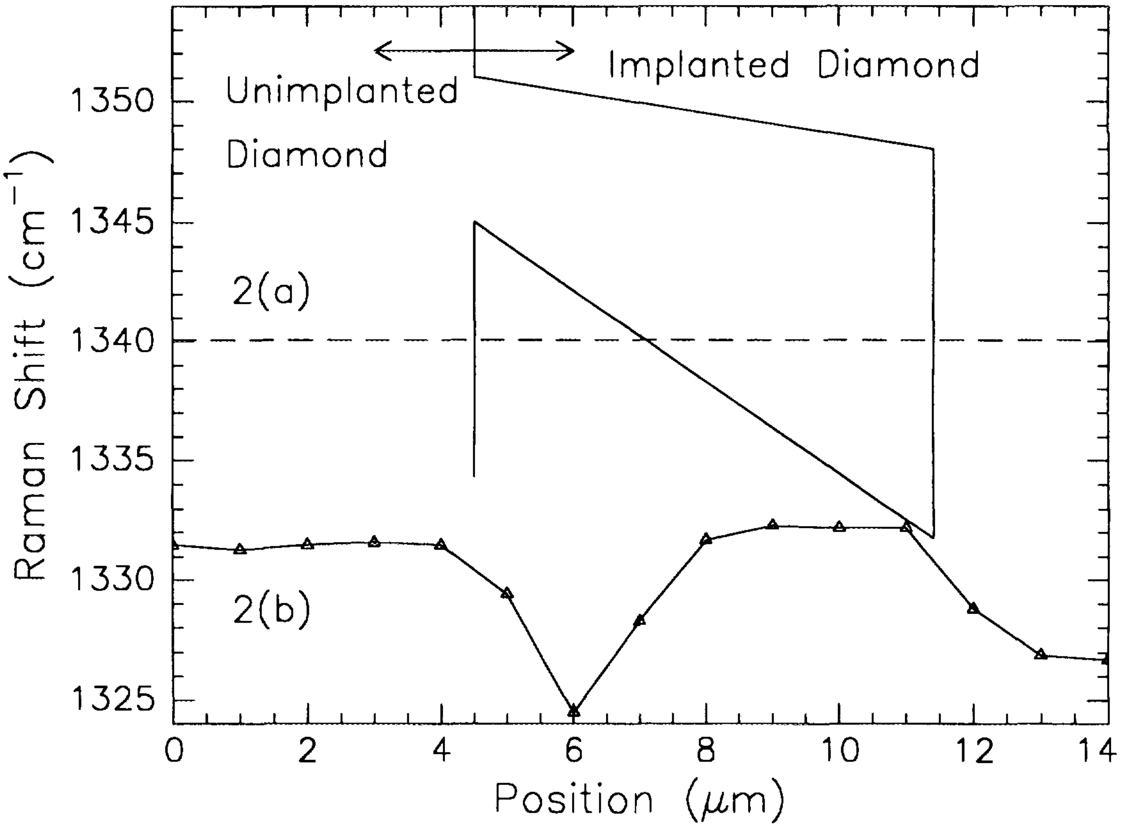

Figure 2. **(a)** The geometry of the "notch" between implanted and unimplanted regions of diamond. **(b)** The variation of the broad component of the 1332 cm^{-1} Raman spectrum of the diamond sample with position along the dotted line shown in (a).

Further interesting results come from the polarisation measurements. In the sample orientation used, the intensity of the bulk diamond line shows little polarisation dependence. In all cases, the polarisation behaviour of the sharp component is similar. Also, the broad component shows little polarisation dependence except on the enclosed tongues of implanted and unimplanted diamond. The large polarisation dependence in these cases indicates that the stress direction is not parallel to the direction of propagation of the laser beam.

In summary, the measurement of the Raman spectrum can give information concerning both the magnitude and the direction of stress in an ion implanted sample. It is possible, in some cases, to determine whether the stress direction is parallel or perpendicular to the sample surface.

References

1. D. S. Knight and W. B. White, J. Mater. Res. **4**, 385 (1989)