A CONFOCAL RAMAN IMAGING STUDY OF OPTICALLY TRANSPARENT BORON-DOPED DIAMOND FILMS

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It is known that micro-Raman spectroscopy is a powerful technique for the characterization of diamond: it is fast, non-destructive and requires no special preparation of the samples. The Raman parameters such as intensity, width, peak frequency and polarization of the diamond line, as well as the presence of other signals, provide fruitful information on the structural and, in some cases on the electronic properties of the samples. Moreover, recent improvements in the implementation of the technique make Raman spectroscopic imaging possible. Different systems have been developed to reduce recording and display times to reasonable levels, and it is now technically possible to produce Raman images with spatial resolution better than 1 µm within some hours.

We will present our efforts to use confocal Raman imaging to investigate the structural, and to some extent, the chemical inhomogeneities that exist in HPHT or CVD diamond crystals and films.

A series of 4 high quality, free-standing optically transparent diamond disks was examined. The first one was nominally undoped, while the three others were boron-doped. A number of boron-related lines at 610, 925, 1045, 1385 and 1485 cm^{-1} were detected and found to vary from one region to another. Even if their origin is somewhat uncertain, their presence enabled the construction of spatial maps of the boron signal intensity over the surface. It was confirmed that boron is incorporated into CVD diamond with significant inhomogeneities. Some of disks were nearly luminescence-free, while for other, it was possible to detect the usual photoluminescence signals of the $[\mathrm{N\text{-}V}]^0$ and $[\mathrm{N\text{-}V}]^-$ centers. In most cases, the intensity of the boron and nitrogen related signals tracked the structure of the grains. The high quality of the disks examined allowed a detailed study of the structure of the grain boundaries to be made. There was evidence for non-diamond carbon being incorporated, mostly into the grain boundaries.

Localized stress variations were also observed. The strained regions were not systematically associated with the incorporation of non-diamond carbon. The grain boundaries and, most probably planar defects, were identified as the main sources of stress.

These results emphasize the amount of variability that can be seen in the microscopic spectra of CVD diamond, although the macro-Raman spectra of such films can appear reproducible. In particular, they confirm that the crystals or films quality cannot be assessed in view of some few single-point measurements.

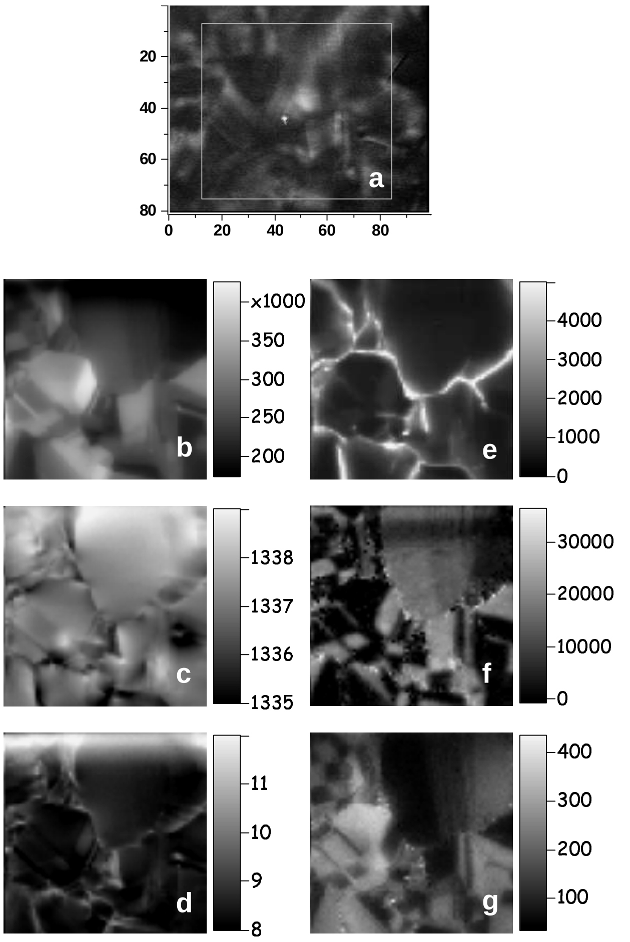

Fig. 1. Examples of confocal Raman images obtained over a 74 × 70 µm probed area, with 1 µm point spacing. The sample was a boron-doped free-standing optically transparent diamond disk. These images were obtained using low spectral resolution. (a) optical image, (b) integrated intensity of the diamond line (a.u.), (c)diamond line position (cm^{-1}), (d) diamond linewidth (cm^{-1}), (e) photoluminescence background intensity (a.u.), (f) integrated intensity of the $[\mathrm{N\text{-}V}]^0$ photoluminescence signal (a.u.), (g) integrated intensity of the 610 cm^{-1} boron-related line (a.u.).

The diamond line frequency and width were obtained by fitting all the individual spectra with a Lorentzian line shape.