



## Confocal Raman Imaging of Diamond Film

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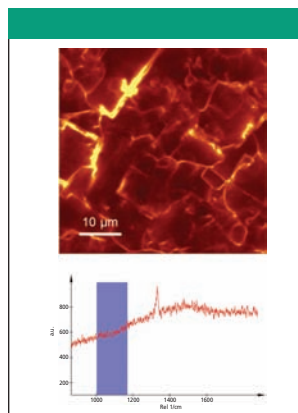
CVD diamond can be easily produced enabling new technologies and new opportunities for research and industry. An important advantage of CVD diamond growth is the ability to control the properties of the diamond produced. To learn more about how the composition of the film on the sub-micrometer scale influences the final product, Confocal Raman Imaging can be used as characterization tool.

In the following study, a polycrystalline diamond film deposited on Silicon was investigated using the WITec alpha 300 Confocal Raman Microscope. A  $50\ \mu\text{m} \times 50\ \mu\text{m}$  area using  $256 \times 256$  pixels (= 65,536 spectra) with an integration time of 50 ms per Raman spectrum was analyzed. For excitation and detection a 100X objective with a 0.9 numerical aperture (diffraction-limited spot size 360 nm, pixel size 195 nm) and 10 mW of power from a frequency-doubled NdYag laser operating at 532 nm was used. A 300 mm imaging spectrometer equipped with a 1800 lines/mm grating and a back-illuminated CCD camera captured the spectra in under an hour; from this multispectrum file, the rest of the images shown in this example were calculated.

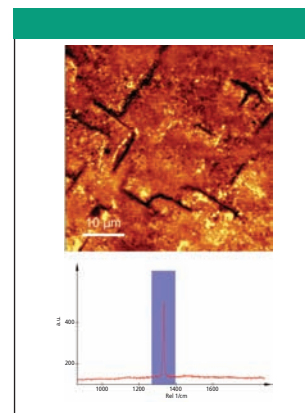
Fluorescence due to impurities is present in many parts of the sample, but strongest at the grain boundaries. To generate the image, the marked area from about  $1000\ \text{cm}^{-1}$  to  $1080\ \text{cm}^{-1}$  (see figure 1) was integrated. Even if the diamond line is included in the integration area, however, the image looks pretty much the same, because fluorescence dominates the spectrum. The quality of the diamond film can be examined by integrating over the diamond line in each spectrum, corrected for the fluorescence background (see figure 2). As one can see, the Raman intensity (sum of the Raman scattered signal) is relatively homogenous; background subtraction removes the fluorescence signal.

The width of the Raman line shows strong local variations (see figure 3). The bright areas correspond to areas with small linewidths, while the dark areas show broadened Raman lines. The color scale is chosen such that areas appear white where the FWHM of the diamond line is below  $5\ \text{cm}^{-1}$ , while the dark areas correspond to linewidths larger than  $15\ \text{cm}^{-1}$ . The FWHM in all spectra varies from about  $5\ \text{cm}^{-1}$  to more than  $60\ \text{cm}^{-1}$ . As can be seen, there are areas containing very sharp lines indicating pure diamond. The small spot size of the excitation laser allows us to detect these variations; a measurement with a laser having a  $50\text{-}\mu\text{m}$  spot would deliver an inhomogeneous broadened spectrum.

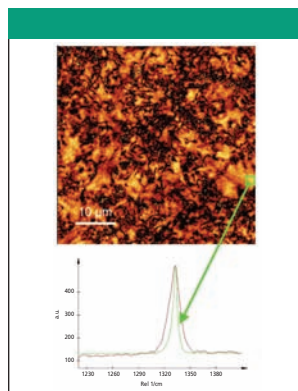
Stress and strain in the material affects the Raman signal by shifting the peaks to lower wavenumbers (tensile strain) or higher wavenumbers (compressive strain; see figure 4). The corresponding spectra have been obtained by integrating over all spectra in the red, green, and blue areas, respectively. The blue spectrum shows a shift of  $5.4\ \text{cm}^{-1}$  to smaller wavenumbers, while the red spectrum is shifted by  $4.2\ \text{cm}^{-1}$  to larger wavenumbers.



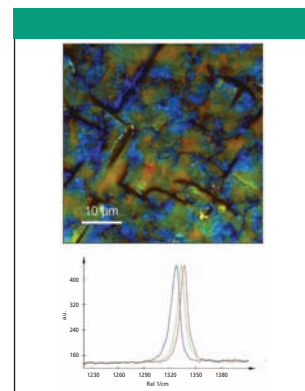
**Figure 1:** The fluorescence background in this image is quantified by integrating the signal over the marked area from  $1000$  to  $1080\ \text{cm}^{-1}$ ; this area does not contain the Raman signal. Note the concentration of fluorescence at the grain boundaries.



**Figure 2:** Raman signal of the diamond line obtained by integrating over the marked area. The fluorescence is not visible because the background was subtracted in each spectrum. Note that not all grain boundaries (dark lines in this image) show a strong fluorescence.



**Figure 3:** In this image, areas where the FWHM of the diamond line is below  $5\ \text{cm}^{-1}$  appear white, while the dark areas correspond to linewidths larger than  $15\ \text{cm}^{-1}$ . The FWHM in all spectra varies from about  $5\ \text{cm}^{-1}$  to more than  $60\ \text{cm}^{-1}$ . The green spectrum has a FWHM of  $5.9\ \text{cm}^{-1}$  and was obtained by integrating over all spectra in the green box, whereas the red spectrum is the average over all 65,536 spectra and has a FWHM of  $15.7\ \text{cm}^{-1}$ .



**Figure 4:** Stress in the diamond film, color coded from red (compressive strain, peak position above  $1333\ \text{cm}^{-1}$ ) to blue (tensile strain, peak position below  $1333\ \text{cm}^{-1}$ ).

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