Conclusion

The study of the generation of structural colour on the wings of the tropical butterfly *Morpho rhetenor* has been presented in this thesis.

A novel method for the investigation of the scattering properties of micrometer-size surfaces has been developed. The spectroscopical study of the microstructure found on the wings of *Morpho rh.* has revealed a broad phenomenology, which required more complex modelling than previously proposed.

Using the theoretical methods employed in the study of photonic crystals, the physical mechanisms behind the scattering properties of the microstructure were identified and its phenomenology was accounted for exhaustively. In particular, the properties of centred rectangular lattices and of tapered diffractive elements emerged as new and central to the microstructure optical properties.

Drawing inspiration from the natural optical device, two- and three-dimensional volume diffractive structures were fabricated using microelectronic processing technologies. All devices were designed to operate at visible wavelengths and therefore were characterised by crystal lattices with sub-micron periods. The two-dimensional structures were dielectric lamellar gratings with multilayer diffractive elements exhibiting previously unreported heights and number of layers. The three-dimensional structures were photonic crystals with an hexagonal, graphite crystal lattice.

From the work presented in this thesis, there are a number of areas where further work might be carried out in the near future. These are summarised

below.

With regard to the phenomenology of the butterfly microstructure, the following is suggested:

- Completion of the characterisation of scattering from the microstructure in the reflection regime over the range of angles which could not be accessed by the experimental setup. This could be achieved by modifying the experimental setup such that retro-reflected light is collected, for example by means of a beam splitter.

- Proof of the grating-like behaviour and establishing the average value of the periods and its variance could be achieved by focussing the white-light supercontinuum to a beam waist the size of a few periods with a microscope objective and observing the dispersive behaviour of the reflected light.

- The occurrence of the collective *Rayleigh* scattering by distributions of small-sized features in the *Morpho* microstructure deserves to be investigated in detail. This would help to understand the relevance of scattering for the diffraction of light, specifically at short wavelengths in the visible spectrum, where the diffractive behaviour is not strictly consistent with that at other wavelengths for the TE polarisation.

- A study of the field localization generated in periodic and irregular arrangements would help to understand the occurrence of *Rayleigh* scattering at specific locations in the spectrograms.

From the fabrication point of view, the following is suggested:

- Use of a metal lift-off technique to transfer the e-beam patterning of the resist into a metal mask could resolve the problems of enlargement of the openings caused by the use of ion beam milling. This would permit production of small structures with higher dielectric filling fractions.

- A less anisotropic dry etch process would enhance the tapering of the structures and permit higher dielectric filling fractions while promoting diffraction into the high orders. It is also expected that tapering would reduce local modulation of the spectra, thus enhancing the bandgap phenomenology.

- A selective wet etch step, ensuing the presented processing of the structures, could allow removal of part of either material in the structures, thus effectively producing tree-shaped diffraction elements. This would make the fabricated structures more similar to the butterfly microstructures.

For the design of a device with a closer behaviour to the microstructure, the following is suggested:

- Fabricating the structure on a quartz substrate would allow the elimination of the strong reflection generated by a silicon substrate and would permit the exploitation of the filtering properties of the multilayered arrangement.

- The asymmetry of the *Morpho* microstructure is fundamental for the extinction of the diffraction orders in the quadrant of specular reflection and the enhancement of the orders in the quadrant of incidence. Implementation of the asymmetry could be achieved by fabricating blazed diffractive elements, *i.e.* triangular elements with a vertical side and a sloping one. This would require successive lithographic steps, whereby a progressively enlarged opening is transferred by etching to progressively shallower depths.

The optical properties of the volume diffractive structures presented in this thesis make them suitable for a variety of applications. The investigation of their function as angle-insensitive and wide-bandwidth beam splitters, spectral and polarisation filters, anti-reflection coatings, transmission gratings and grating couplers, and as omnidirectional reflectors is recommended in connection with their specific application.