Chapter 6 – Summary and Conclusions

The following chapter summarises the important results of this work and what they show. Following this I will suggest some further experiments that it would be sensible to attempt, but that were beyond the scope of this project (either due to financial or time constraints).

6.1 RF-Deposition of Amorphous Carbon Phosphide

Studies in this area have shown:

- Films with a P:C ratio of 3:1 were produced.
- The effect of annealing these films was to generally increase the bonding between C and P.
- Changing gas mixture, the ion energy, or the substrate temperature during deposition tunes the optical band gap of these films.
- An increase in ion energy decreased the P:C ratio within the films, but increased the P-C bonding ratio.
- Virtually hydrogen and oxygen free films were produced.
- Films deposited at high temperature are very thin, with higher deposition ion energies the film is thicker.
- All films produced were amorphous.

This area has been explored quite thoroughly, other areas that may be interesting to explore would be:

- Increasing the substrate temperature further and increasing the ion energy further. This was not possible due to heater and powered electrode design.

- Changing the gas mixture, perhaps with gases that already contain C-P bonds. This was not possible as special MFCs would need to be bought, also some of these compounds are extremely toxic.
- Use other types of CVD such as Microwave Plasma enhanced CVD and hot filament CVD. This would change the film growth mechanism from physical to chemical and allow gentle surface chemistry to occur.
- Extending the range of the work with different pressures, this would involve the replacement of the current rotary pump on the chamber with a pump that allows a lower base pressure.

6.2 Pulsed Laser Ablation at the Solid/Liquid Interface

Studies in this area have shown:

- Diamond has been produced using a novel graphite/cyclohexane combination.
- Two forms of crystalline carbon phosphide may have been found, but as the experiment is not reproducible this cannot be proved.
- High laser fluences tend to produce more crystalline material.
- Evidence (OES and SIMS) has been presented that shows that the laser interacts with the solid and the liquid.

Other aspects of this area that may be interesting to explore are:

- Optimisation of deposition parameters, for example laser fluence and the effect of the form of the target (crystalline material was only observed at maximum laser fluence; a more powerful laser would allow this to be fully explored).

- A detailed study of the conditions within the ablation plume / cavitation bubble.
- The production of other interesting materials by this method such as carbon nitrides.

4.3 Further Work

It would be interesting to use conventional HPHT methods to attempt to produce crystalline carbon phosphide. Theoretical studies by Claeyssens *et al*[1] have shown that the minimum energy structure of carbon phosphide is also the minimum volume structure. As there has been a lack of success producing crystalline carbon phosphide by low-pressure CVD methods, it would be sensible to try an HPHT method. A relatively easy method may be using a diamond anvil cell; many of these pieces of apparatus exist in Universities around the country.

Also as seen in Chapter 1 the only successful recorded production of a compound containing only carbon and phosphorus was in 1921[2]. It was not possible to dissolve this solid in any available solvents and it was resistant to attack by strong acids and bases. As there are a much larger range of solvents, acids and bases it may be interesting to investigate this compound further, annealing it, or using it as an ablation target. This would hopefully cause rearrangements of the structure and crystallisation. An attempt was made at repeating this experiment, but it was unsuccessful (Appendix A).

4.4 References

1 F. Claeyssens, N. L. Allan, P. W. May, P. Ordejon and J. M. Oliva, Chemical Communications**,** 2494-2495 (2002).

2 E. de Mahler, Bull. Soc. Chim **29,** 1071 (1921).