Sensing with Photonic Crystals

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What are Photonic Crystals?

Photonic Crystals are structures that, due to their optical properties, only allow the transmission of certain frequencies (colours) of light. These structures are formed by two or more non-absorbing optical media with spatial periodicity and high contrast in their refractive index. The spatial periodicity and the contrast in dielectric constant form light stop bands known as photonic band gaps. Frequencies within these bands are reflected or diffracted out of the crystal, forbidding their propagation throughout the crystal.

In the same manner, just as defects change the electronic bands in a lattice, dielectric defects will change the photonic bands of the crystal.

Frequency vs Photon momentum

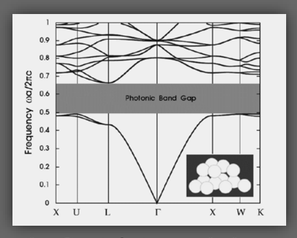

Fig 2. Photonic Crystal transmission spectrum extracted from [1]

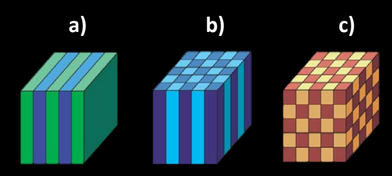

Figure 1. a) 1D, b) 2D, c) 3D Photonic Crystal structures extracted from [1]

Aims of the Project

This project aims to research the viability of using the optical properties of Photonic Crystals to be used as low cost, high-sensitivity and high-selectivity sensors by observing and characterising the variation in their optical properties when exposed with different analytes, identifying the best material/analyte combinations regarding their sensitivity.

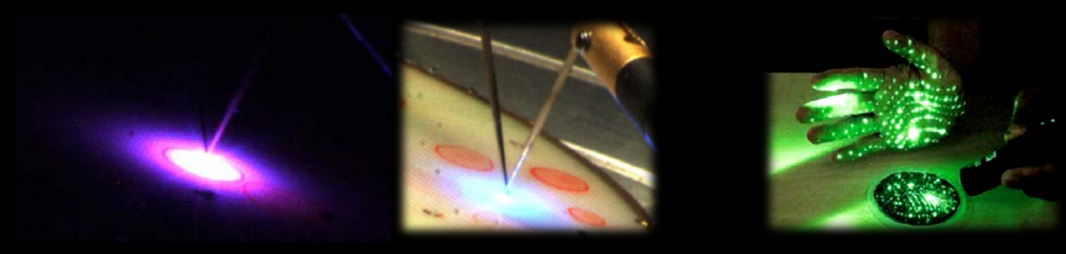

Figure 3. Wafer manufactured Photonic Crystal under testing. extracted from [4]

Photonic Crystals as Sensors

Photonic Crystals will give us a new way to detect physical quantities with high sensitivity and selectivity. Because the optical properties of the crystals just depend on the contrast of their refractive index and the scale of the periodicity, their structure can be made of biocompatible materials like polymers, making them the perfect option for Medicine and Health care applications. Also, this will allow us to use the already well stablished microelectronic industry, and the use of low-cost materials in their fabrication.

Fig 4. Photo of Nano replica molded plastic Photonic Crystal biosensors. Extracted from [3]

Why the project matters?

In fields such as Chemistry and Biology, the interaction between the instrument and the measured quantity is a critical factor. This because high sensitivity and selectivity is required without modifying the analyte. For this reason, optical detection methods such as Surface Plasmon Resonance, Hologram biosensors, among others; have gained popularity in areas of great importance such as Medicine and Health care. Nevertheless, these methods require really complex and expensive instruments, making it difficult for the general population to monitor their health continuously and efficiently on a daily basis.

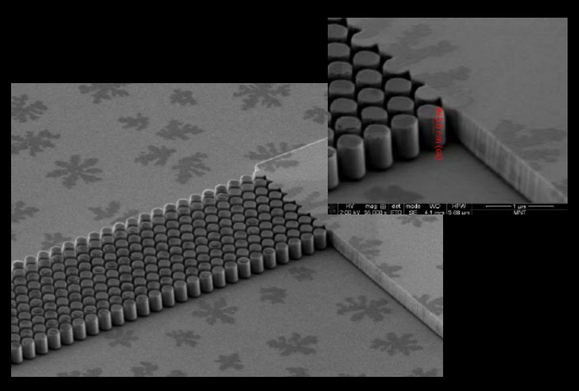

Fig 5. Photonic Crystal structure using SEM extracted from [4]

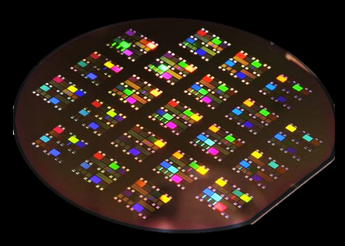

Fig 6. Photonic Crystal Nanostructures in a wafer extracted from [5]

Future Applications

Various applications using Photonic Crystals as sensors have been proposed and researched. Portable health care devices, such as glucose monitoring devices using tear fluid, have been successfully tested. Also, several devices using this technology have proven high potential in early illness detection by showing good sensitivity and selectivity in antigen identification.
Another application under research that has given interesting results, is the viability to 'observe' nanoparticles by placing CCD arrays in the Photonic Crystal arrays.

References

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[2] C. Sibilia, T.M. Benson, M. Marciniak, and T. Szoplik, *Photonic Crystals: Physics and Technology*, Italia Springer-Verlag, 2008, Part 1.
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[4] M. Charlton, "Lecture 8: Photonic Crystal Manufacture for LED/Solar cells", ELEC 6009, University of Southampton, Southampton, 2015.
[5] M. Notomi, (2014), *Photonic Nanostructures*, [Online], Available: http://www.brl.ntt.co.jp/group/ryouna-g/