

Fabrication of Distributed Bragg Reflectors (DBR) by spin-coating for the development of a novel optical ultrasound sensor

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Objective

Investigate a new method of fabricating a Distributed Bragg Reflector (DBR) via spin-coating for the design of a novel optical ultrasound sensor.

Novel optical ultrasound sensor

Optical ultrasound sensors can overcome the limitations of standard piezoelectric sensors (e.g. bandwidth and sensitivity).

The ultimate aim is to design a novel ultrasound sensor based on laser technology (Fig. 1).

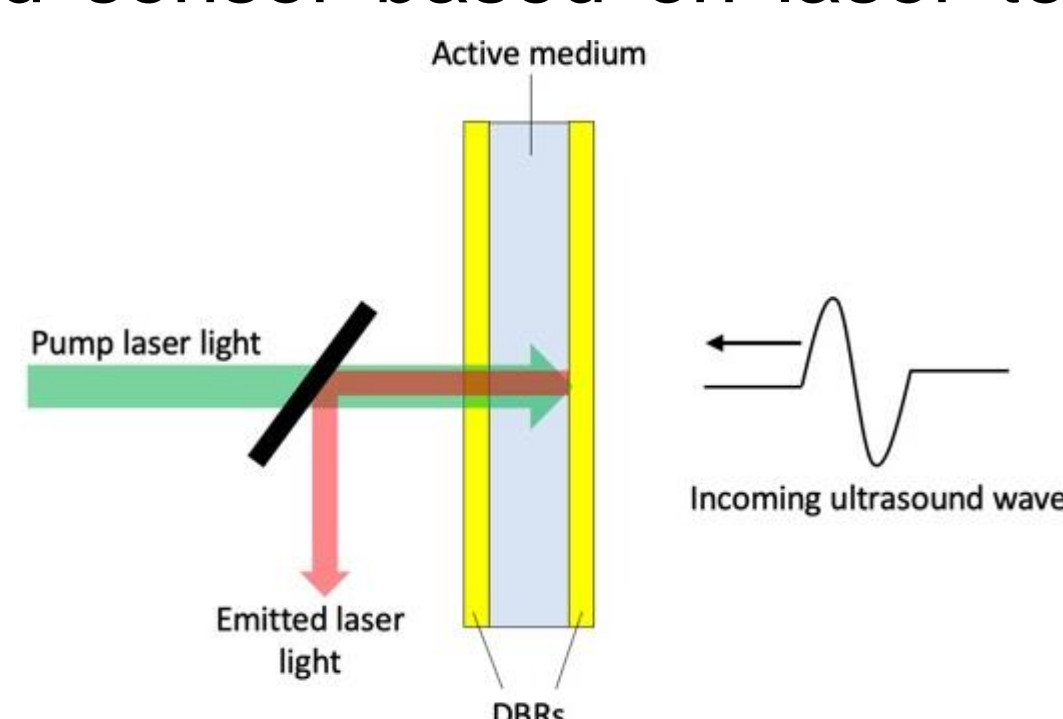


Figure 1: Schematic of a novel ultrasound sensor composed of two DBRs, an active medium and a pump source.

As an ultrasound wave compresses the sensor, the wavelength of the emitted laser light will change. By monitoring this change the ultrasound wave can be captured.

The focus of the work presented here is on the design and fabrication of the DBRs which are a key component of the novel sensor.

Distributed Bragg Reflector (DBR)

A Distributed Bragg Reflector (DBR) is a reflector formed from multiple layers of alternating materials (Fig. 2)

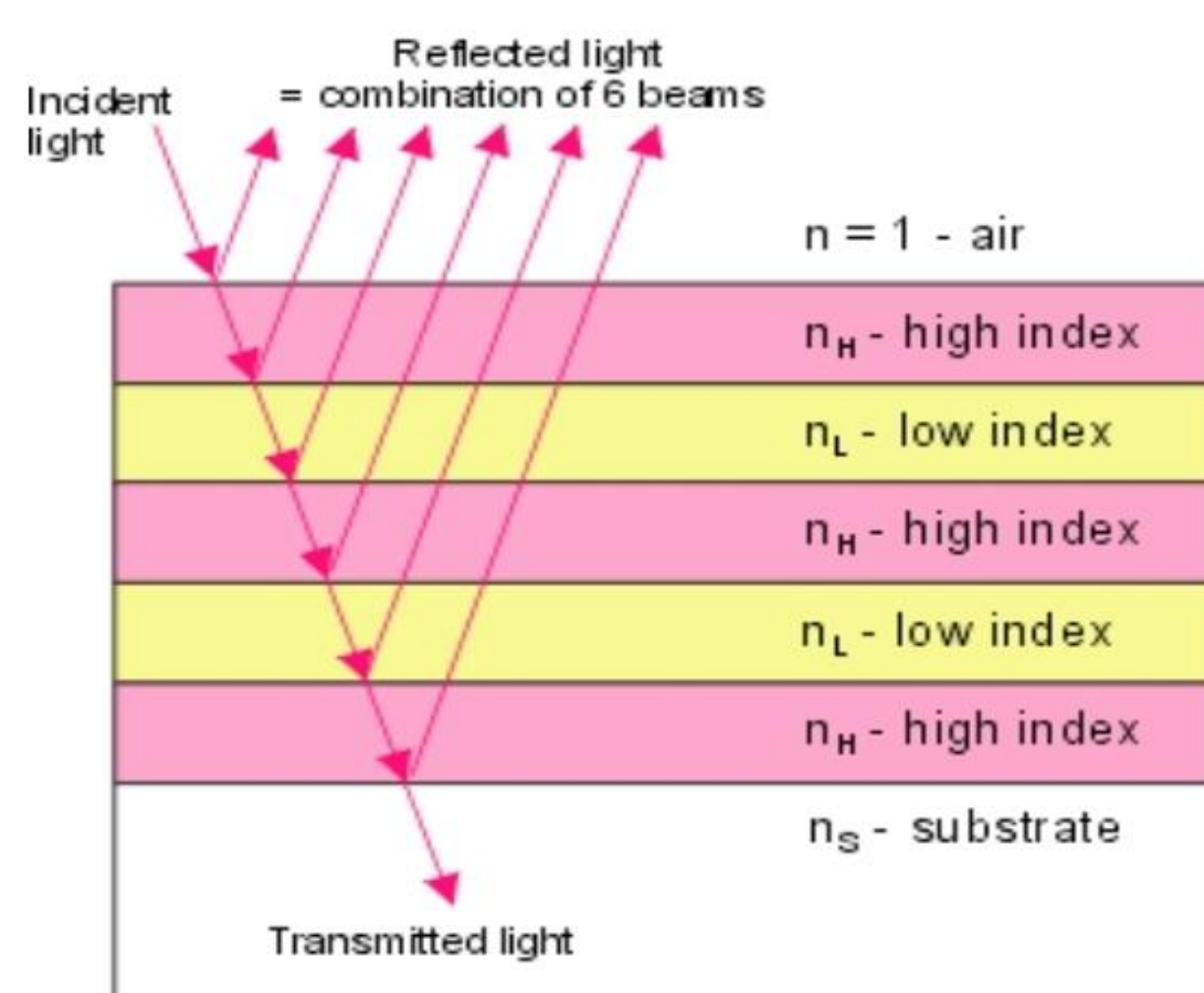


Figure 2: A schematic of a DBR

- The thickness of the layers determine the **centre wavelength** (Fig. 3).
- Their refractive index determine the **bandwidth** (Fig. 3).
- The number of layers determine the **maximum reflectivity** (Fig. 3).

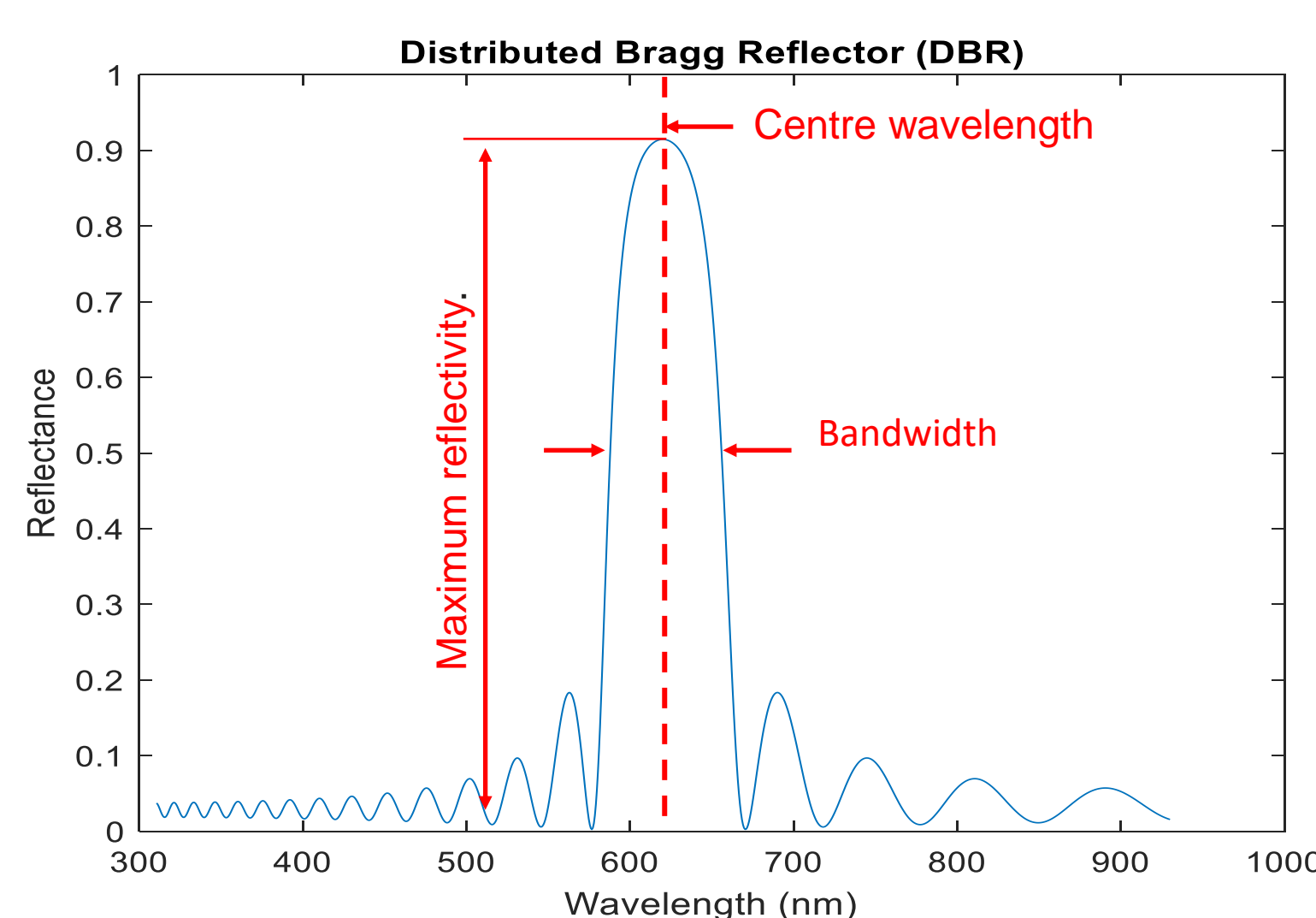


Figure 3: Reflectance of the DBR as a function of wavelength

Fabrication method

Design parameters:

- Cellulose Acetate (CA) and Polyvinylcarbazole (PVK) were selected as the low and high refractive materials.
- To achieve a **centre frequency** of 620 nm, each layer needs to be 155 nm thick.
- From the modelling (see fig. 2) and literature, it was estimated that **14.5 layers** would be required.

Spin coating:

It was necessary to determine the optimum rotation speed of the spin coater to achieve a film thickness of 155 nm. This was achieved as follows:

- 5 glass slides were **spin-coated** with a solution of CA (another 5 with a solution of PVK), each with a **different rotation speeds** (e.g. 1000, 2000, 3000, 4000, 5000RPM)
- Thickness** of the layer of materials were measured using a profilometer (fig. 6) and the result plotted in fig. 4 and 5 for CA and PVK respectively.
- The **optimum speed** required to obtain the desired thickness was then determined from the plots.

Fabrication of the DBR:

Once the optimum rotation speed was determined, a DBR mirror was fabricated by alternatively spin coating thin films of PVK and CA at the desired thickness. Three DBR mirrors, **each composed of 14.5 layers**, were created (fig. 7).

Results

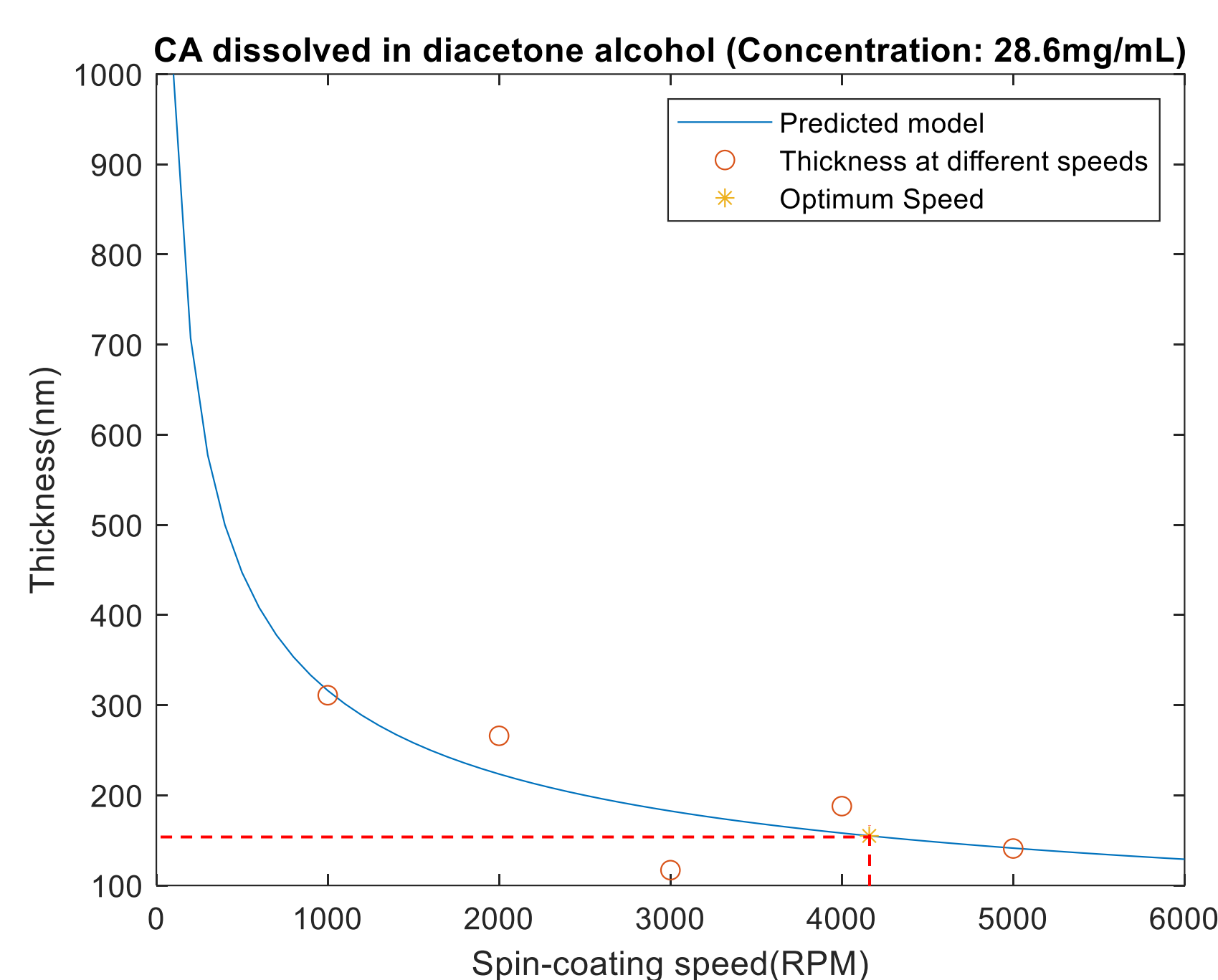


Figure 4: CA material thickness as a function of spin-coating speed

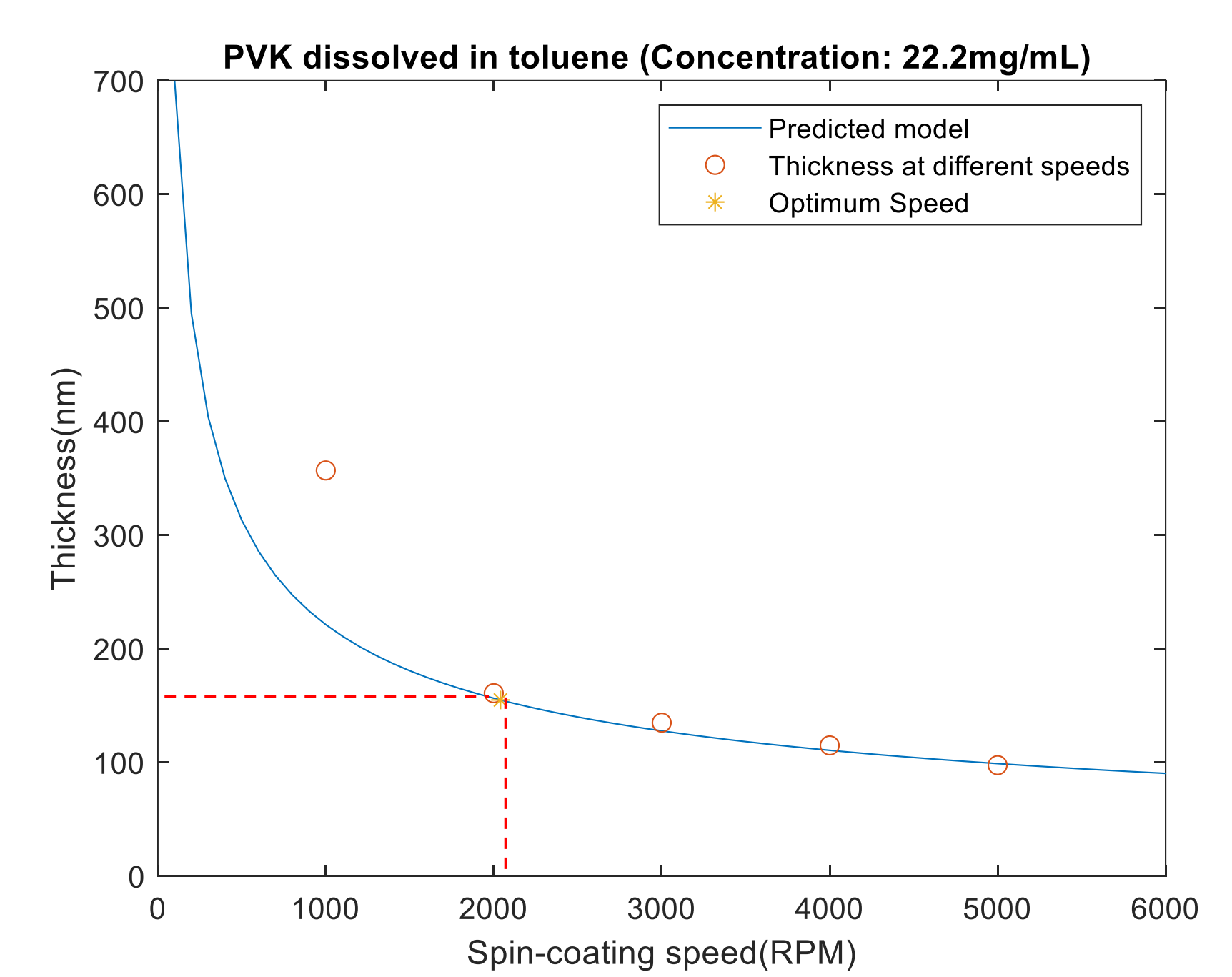


Figure 5: PVK material thickness as a function of spin-coating speed



Figure 6: A contact profilometer which measures the thickness of the layers CA, PVK and PMMA

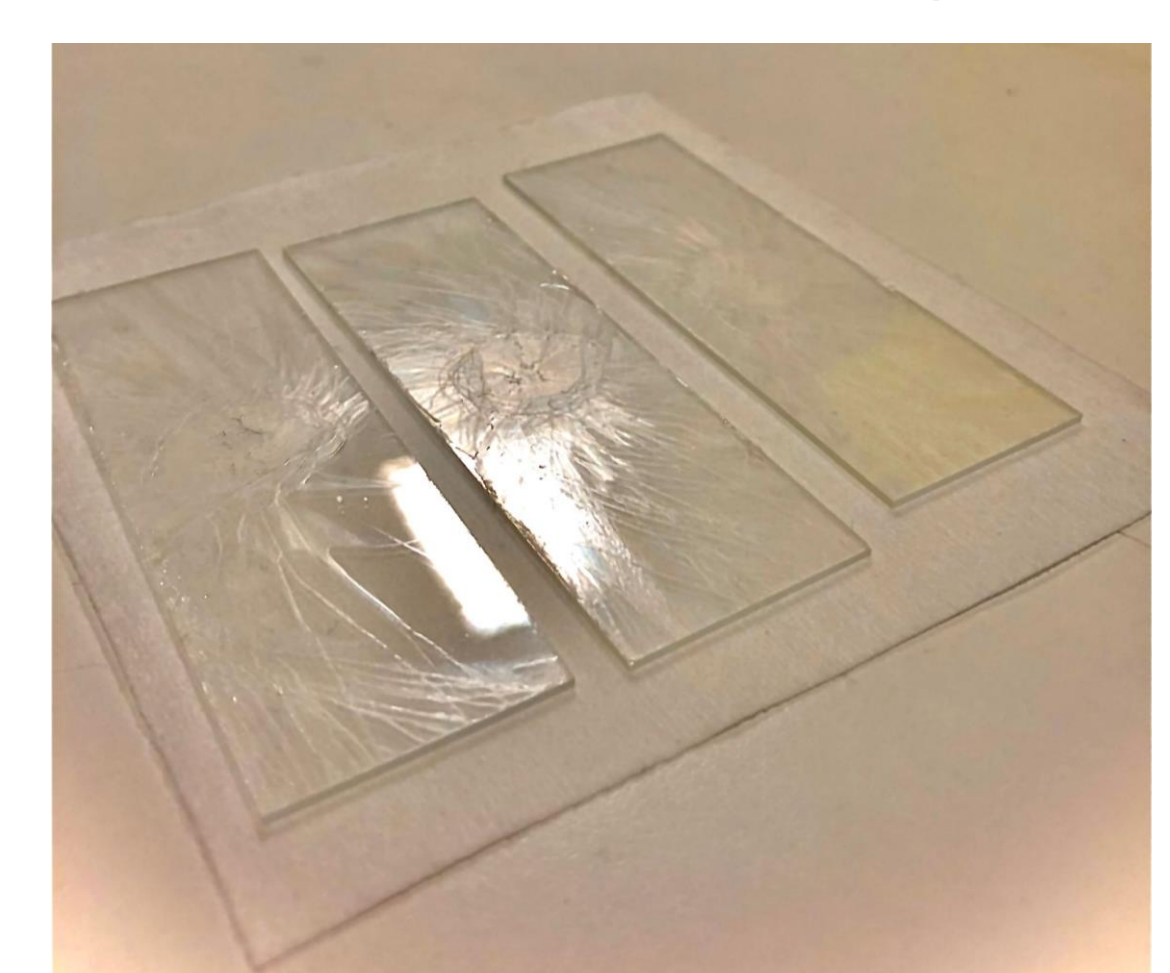


Figure 7: 14.5 Layer DBR mirrors showing reflectivity

Conclusion

- Predictive models** have been generated for the thickness of films of the materials CA and PVK, proving that the thickness **varies with the function of spin-coating speed** at the determined concentrations (figure 4, 5)
- This cost-effective fabrication method will ultimately be used to **create DBRs** for the novel optical ultrasound sensor being developed at UCL.
- The development of this novel optical ultrasound sensor has a broad premise and can be applied to **medical diagnosis and therapy**. Potential applications include the **detection** of breast cancer, skin pathologies or cardiovascular diseases.

References

- Fast and simple fabrication of organic Bragg mirrors—application to plastic microchip lasers - IOPscience [Internet]. [cited 2022 Aug 5]. Available from: <https://iopscience.iop.org/article/10.1088/1612-2011/10/5/055808>
- Yang Y, Zhou Y, Liao Z, Yu J, Cui Y, Garcia-Moreno I, et al. Mechanically tunable organic vertical-cavity surface emitting lasers (VCSELs) for highly sensitive stress probing in dual-modes. Opt Express [Internet]. 2015 Feb 23 [cited 2022 Aug 2];23(4):4385–96. Available from: <https://opg.optica.org/oe/abstract.cfm?uri=oe-23-4-4385>
- Chapman N, Chapman M, Euler W. Modeling of Poly(methylmethacrylate) Viscous Thin Films by Spin-Coating. Coatings. 2021 Feb 9;11:198.

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