

Dip Coating vs. Spin Coating

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The aim of this document is to provide an overview of current Hard Coating technologies. Any information provided is not binding, can and will be changed without further notice. If you have questions, contact the owner of the document (marcello.pote@satisloh.com).

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1. Dip Hard Coating Technology

This document provides an overview of current Hard Coating technologies used in mass production and Rx lens manufacturing. It explains the differences, advantages, and disadvantages of both Dip and Spin Coating technologies with respect to market needs and new materials.

Dip Coating technology using hard resins was developed in the early 80's to improve FDA Drop Ball Test results and the scratch resistance of CR39 lenses. The Hard Coating process usually follows lens casting (for mass produced stock lenses) or Rx surfacing (in Rx laboratories).

The development of High Index and Ultra High Index plastic monomers, which are very soft and easily scratched if not hard coated, led to the introduction of high quality Dip Coating processes with substrate/lacquer index matching properties. Index matching provides increased visual comfort and improved cosmetics for end users as explained later in this document.

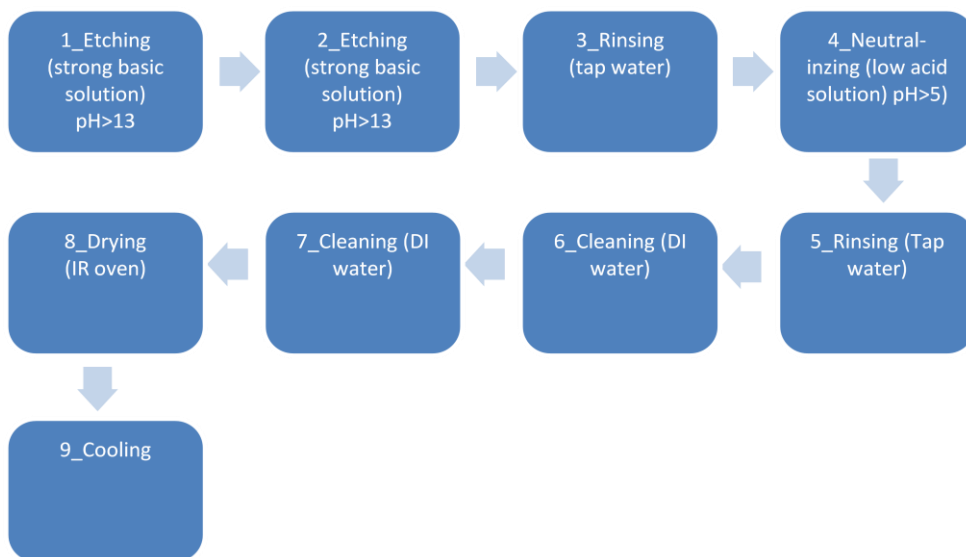
More complex and highly effective AR coatings further spurred improvements of the Hard Coating process, resulting in high performance Hard/AR coating packages.

1.1 Basics of Dip Coating Technology

This Hard Coating process is generally performed by dipping lenses into a liquid lacquer (polysiloxane resin) that is applied to both sides and then hardened by thermal curing. Dip Hard Coating Technology has been originally developed for uncoated lenses, irrespective if they come from stock or Rx production, although some labs over-coat on top of pre-existing hard-coatings after first applying a primer layer.

Lenses are usually activated and cleaned in a line of multiple etching /rinsing baths. This prepares them for the hard coating.

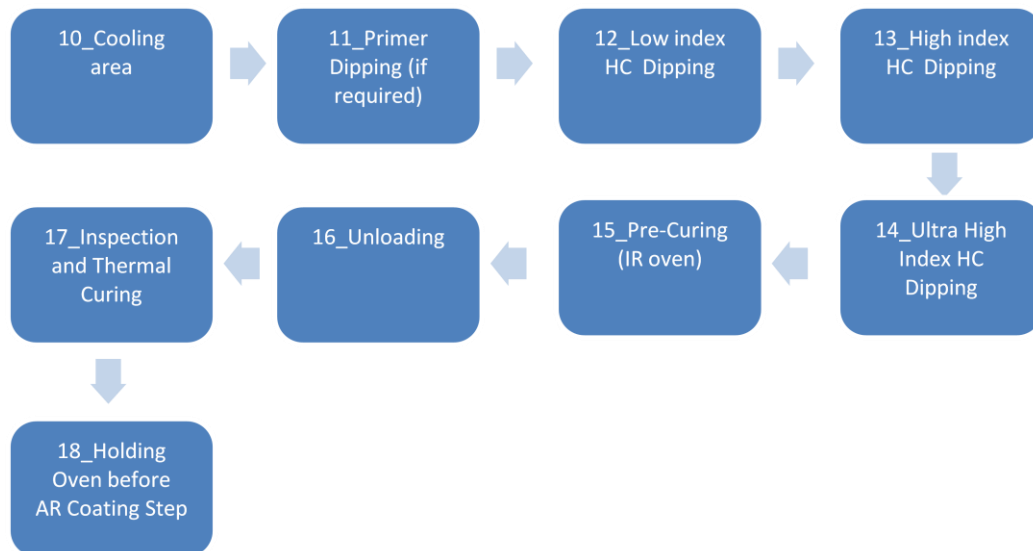
Below is a typical schematic of the activation and cleaning process flow:



The adhesion between substrate and lacquer is ensured by chemical etching prior to Hard Coating and a final thermal curing step, usually completed in static ovens.

Then lenses are automatically transferred (by carrier or transfer robot) to the coating area which must be controlled regarding temperature, relative humidity % and clean air flow (Class 100).

Below is a simple schematic of the coating process flow:



After the Dip Hard Coating process, lenses are thermally cured for 60-180 minutes in static ovens and are then ready for AR coating in dedicated machines.

Lenses that are meant to be only Hard Coated, like CR39 and sunglass lenses, can go directly to final inspection before delivery.

The entire Dip Hard Coating process takes between four and six hours, including thermal curing.

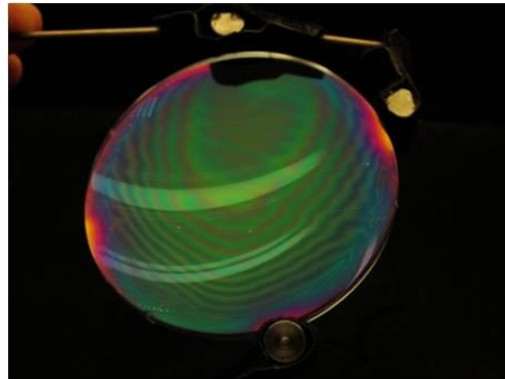
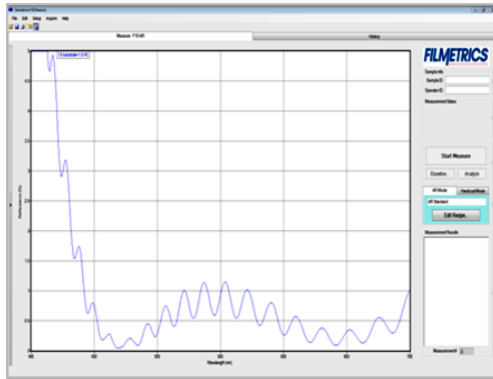
1.2 High Index Lenses and Dip Hard Coating

In the last 15 years, the growth of ophthalmic High Index materials led to further development of High Index lacquers to match, as close as possible, the refractive index of the lens substrate. At the same time these Hard Coatings have to provide good scratch resistance and adhesion with the subsequently applied AR coatings.

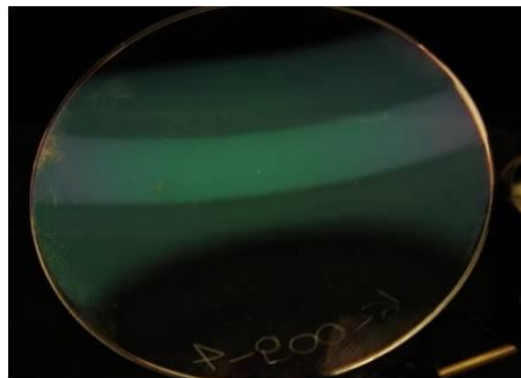
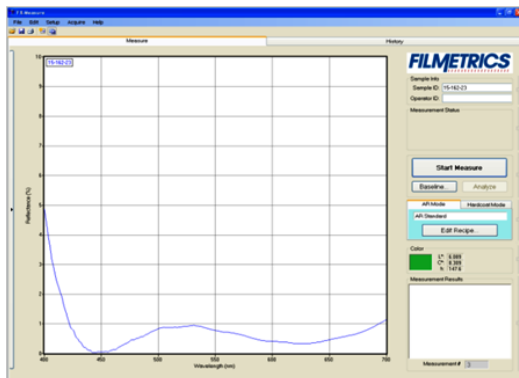
High Index lenses show a lower transmission compared to CR39. This makes AR coatings a must for good optical performance of a High Index lens. AR raises the transmission percentage from a low 90-92% of an uncoated/HC 1.60 lens up to the 99% of an AR coated High Index lens (for comparison, uncoated CR39 has a transmission percentage of 96%).

One of the main advantages of Dip Hard Coating technology is the significant reduction of the so-called Newton Rings Effect, which is generated when light passes through media with different refractive indices. On a lens this unsightly effect is created by the difference in refractive indices between substrate and applied Hard Coat.

The chart and picture below show a reflection measurement and the related Newton Rings Effect for a $n=1.6$ lens which is hard coated with a $n=1.5$ lacquer plus a standard AR coating.



When the refractive index of the lens and the Hard Coating lacquer are closely matched, the above effect is reduced to almost zero. Below a reflection measurement and related Newton Rings Effect for a $n=1.6$ lens hard coated with a $n=1.6$ lacquer (perfect refractive index matching).



Further development in High Index materials occurred and now High Index monomers are available up to an index of $n=1.74$. Dip hard coating lacquers are available with similar refractive indices. The production complexity (and the cost per lens) of such materials is quite high, making these lenses a "niche" product for high minus prescriptions. The matching lacquers are relatively expensive and need experienced operators to handle, apply and maintain.



Satisloh Dip Coating machine

Advantages and disadvantages of Dip Hard Coatings:

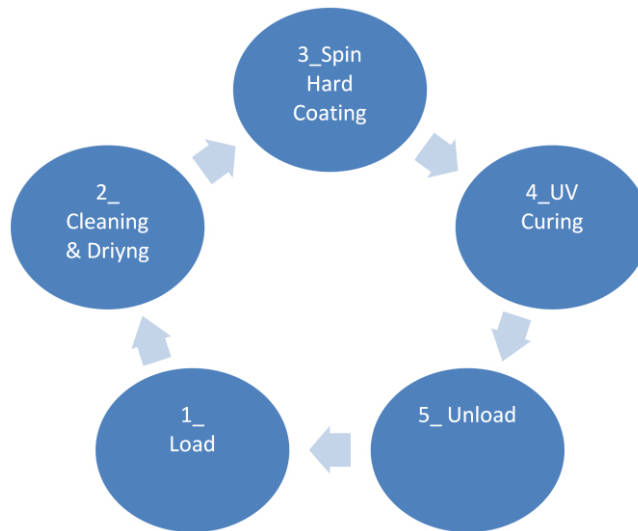
Advantages	Disadvantages
+ Same coating on both sides	- Clean room is required
+ Best scratch resistance	- High chemistry cost if lens volume is low
+ Inexpensive chemistry if lens volume is high	- Requires high level of discipline and training to avoid yield issues
+ Index matching of lacquer and substrate	- Good dip coating equipment is expensive

2. Spin Hard Coating Technology

Spin Hard Coating Technology has been developed for different applications, primarily in the USA where Polycarbonate has a considerable market share. Due to its low scratch resistance, Polycarbonate blanks are usually only available already Dip Hard Coated. However, the Hard Coating on the concave (back) surface of the lens is removed in standard Rx production. This creates the need to coat the back side of the freshly surfaced lens with a protective Hard Coating which also reduces the material's natural haze, and allows passing the FDA Drop Ball Test. It was also developed for the purpose of tinting because Polycarbonate lenses are non-porous and will not accept a tint when uncoated. The only way to apply a Hard Coating solely on the back side of a lens is with Spin Coating Technology.

2.1 Spin Hard Coating Technology Basics

Spin Coating lacquers are applied to the back side of a lens while it spins, optimizing lacquer distribution and thickness. Most Spin Coating lacquers currently available are UV-curable, so the curing step is performed by exposure to a UV source that enables the polymerization of the lacquer in a very short time: from 10-15 seconds up to 45-50 seconds. The latest generation Spin Coating machinery is fully automated and carries lenses through different process steps, as shown below.



A Spin Hard Coated lens will have different lacquers on both sides, which can increase the “Newton Rings Effect” (occurring because of index mismatch between substrate and lacquer). The UV curing process and the chemistry of Spin Coating lacquers is known to make lens production quite fast and inexpensive, but the trade-off is a reduction in quality regarding scratch resistance (if a tintable lacquer is used) and cosmetic quality due to the lack of index matching.

2.2 All Solids and Solvent Base Spin Lacquers

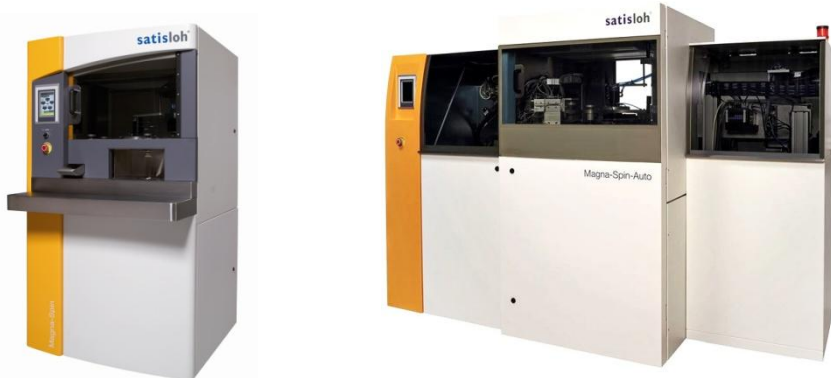
Responding to the request for improved quality of standard All Solids Spin Coating lacquers (AS), companies developed the so-called “Solvent Based Spin Coating Lacquers” (SB) which have a higher content of solvents compared to AS lacquers.

The primary goal of these new lacquers was to improve both mechanical and scratch resistance properties as well as the adhesion on popular High Index lenses. Solvent Based lacquers have good adhesion on all substrates up to $n=1.67$ and when combined with an antireflective coating, abrasion resistance is as good as with Dip Hard Coatings. In fact, the scratch resistance of newer Solvent Based Spin Coatings can now match even the best Dip Coatings as long as a lab chooses non-tintable resins.

2.3 Spin Coating and Fast Delivery Labs

Aside from the reduced footprint of a Spin Coating Lab compared to a Dip Coating Lab, another advantage of Spin Coating technology is speed. The Spin Hard Coating process takes only a few minutes, then lenses are ready for AR coating on the spin coated back surface.

This advantage is fully leveraged when 1) lenses are Spin Hard Coated on the same block that is used in surfacing and 2) semi-finished blanks that have been pre-hard coated and pre-AR coated on the convex (front) side are being used. The plastic blocks utilized with modern alloy-free blocking technology provide full protection of the already completed lens front side (HC + AR + Top Coat), enable the option to hard and AR coat the lens back side on the block, and make completion of a finished lens in less than two hours possible. Satisloh’s automated version of its Spin Coating equipment loads and unloads lenses automatically, making it a perfect fit with a fully automated lens production line.



Satisloh Spin Coating Equipment (Manual version and Automated version)

Advantages and disadvantages of Spin Hard Coatings:

Advantages	Disadvantages
+ Easy process	- No index matching
+ No clean room required	- Different coatings on front and back side
+ Relatively low cost equipment	- Expensive chemistry if lens volume is high
+ Good for low volume operations	
+ Tintable lacquers available	

CONCLUSION

Both Hard Coating technologies described in this document enable manufacturers to produce quality coatings. Choosing the right technology for each application is dependent on production volumes, automation needs, required lens delivery times, and market requests.

Dip Hard Coating produces better optical (index matching) products and highest performance regarding mechanical resistance; cost per lens is advantageous for mid to high volume labs.

Spin Hard Coating offers a significantly shorter production time and allows processing lenses in pairs, reducing wait time typical in batch production. Spin coating, if using a non-tintable solvent based resin, can now match the scratch resistance of most dip coatings. From a cost perspective, Spin Coating technology is most beneficial for low to mid volume laboratories.