Taking the Mystery Out of AR

A Technical Resource Guide

Satis Vacuum

Letter from the President

Dear Eyecare Professional:

Anti-reflective lenses represent the fastest growing segment of the American eyewear market. The AR Council estimates that 19% of lenses sold in the US in 2000 were AR lenses. This represents substantial growth over previous figures, but is just the tip of the iceberg. During the next few years the growth rate of AR lenses in the US will accelerate to levels never before experienced in our market. This acceleration is due to a number of factors:

- The quality of AR lenses being produced today is dramatically better than even 2 years ago, and continues to improve as more and more coating facilities control the entire prescription fabrication. The improved quality of AR is resulting in increased word-of-mouth referrals among consumers and increased patient loyalty for practices.
- Larger retail chains are promoting AR lenses in unique and exciting ways. Some chains are reaching penetration rates exceeding 50%, and others are quick to follow.
- A number of lens manufacturers are introducing 100% AR lens brands while supporting those brands with advertising campaigns designed to bring patients into your offices with questions about how they can personally benefit from anti-reflective lenses.

In parts of Europe, AR penetration exceeds 75%, while over 90% of consumers in Japan wear AR. The US market needs to prepare itself for the boom in AR business, and one of the best steps eyecare professionals can take begins with product education. Although a number of AR marketing guides have been recently distributed few, if any, were created with the aim of taking the mystery out of the technical aspects of AR.

Satis Vacuum is the world's leading producer of vacuum coating equipment. Many of the branded AR lenses you dispense on a daily basis were most likely produced by Satis Vacuum equipment. Our unique qualifications in this arena have allowed us to provide you with this brand neutral Technical Resource Guide, designed to further your education on how AR coating works and the complex process with which it is applied. We hope it will increase your understanding of the AR process and ultimately increase your success when presenting AR lenses to all of your patients!

Sincerely yours,

Larry Clarke
President and CEO
Satis Vacuum of America, Inc.
csr@satis-vacuum.com
877.409.9401

What are anti-reflective lenses?

Simply stated, anti-reflective lenses include any lens substrate (glass, plastic, polycarbonate or high index) which is enhanced by an incredibly thin, multi-layer coating that virtually eliminates lens reflections. By allowing all available light to pass through the lens, your patients will experience the ultimate in visual acuity. Today's AR lenses have many benefits for the average eyecare patient, but the two most important benefits are increased visual acuity and cosmetic appeal.

Increased Visual Acuity

A standard CR-39® plastic lens loses 8% of available light caused by reflected light from both the front and back lens surfaces. Reflections not only decrease visual acuity, but also cause undue eye strain because of increased ghost imaging. And the amount of reflection only increases as the index of the lens goes up! While high index lenses offer wearers flatter and thinner lenses, decreased light transmittance means they lose upwards of 15% of available light (see light transmission table below). Do your patients want lenses with 85 to 92% light transmission, or the optimal visual performance of AR lenses which provide 99% light transmission?

Cosmetic Appeal

Remember the expression, "a person's eyes are windows to their soul"? If one's true expression and honesty can be seen in their eyes, then why hide behind annoying lens reflections? AR lenses not only help a patient look better, but more importantly, allow them to be seen in a more natural view. Recent focus groups and marketing studies show that the average consumer feels it is important to allow people to see their eyes when they communicate. Only AR lenses allow your patients' eyes to be seen better, and look better, too!

LIGHT TRANSMISSION = CLEAR, CRISP VISION

Lens Material	Index	Without AR	Including Multi-Layer AR
CR-39®	1.50	92.06	99.1
Glass	1.52	91.4	99.2
Polycarbonate	1.59	89.4	99.0
High Index Plastic	1.60	89.4	99.0
Super High Index Plastic	1.67	87.8	98.2

Patient Education is a Dispenser's Best Friend

- Begin by merchandising the waiting area. Ask your AR provider for brochures and point-of-purchase demonstrators.
- Recommend from the chair. Write AR lenses on the Rx form.
- Hand-off to the dispenser, reinforcing your recommendation.
- Wear AR…the strongest testimonial is to wear what you recommend!
- Demonstrate by using a frame with one anti-reflective lens, and one uncoated lens. Put it on and ask your patient which lens they would prefer to wear.

Special Delivery

Ensure the future success of anti-reflective lenses! Take a few moments at the time of delivery to explain the simple steps of **properly caring** for anti-reflective lenses.

Because anti-reflective lenses are more clear and less reflective, dirt is more noticeable and lenses may need to be cleaned more often. For best results, clean lenses using an eyeglass cleaner specially designed for anti-reflective lenses. For extended life, always rinse off or lightly brush off any particles of dirt from lens surface prior to cleaning.

Anti-reflective lenses will help you SEE BETTER and LOOK BETTER, and with a minimal amount of care, you can expect years of durable performance!

Lens Care Products

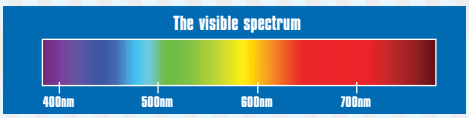
Recommend a regular lens cleaning regimen, complete with easy-to-use products that fit the active lifestyles of your patients. Ask your AR provider about what lens cleaning products they currently have available:

- Lens spray cleaner, specially designed for anti-reflective lenses
- Lens cleaning cloth
- Pre-moistened, disposable lens cleaning cloths…great for travel and everyday use
- Recommend lens cleaning products for the home, office, car, everywhere they are most likely to be used

FREQUENTLY ASKED Questions?

Why do some AR lenses reflect different colors than others?

When seen from an angle, all AR lenses reflect a small amount of color/hue. This is a natural phenomenon associated with the reflectance curve of a broad band AR coating across the visible spectrum of light. AR coatings have a peak reflectance at some point on the visible light spectrum, and it is the color associated with that peak which is reflected more than other colors of the visible light spectrum. Most AR producers choose their peak color reflection based on customer research, consistency of manufacturing, and consumer focus group information. Most AR coatings tend to have peak reflectance in the 520-550nm range of the light spectrum, the green area of visible light. This is the easiest color to hold consistently during manufacturing. Some manufacturers tend to move the curve closer to the blue or purple end of the spectrum, while others move the peak towards the yellow.



What is the most important factor to consider when ordering AR lenses?

Without question, the most important factor that will determine overall AR quality is the brand of hardcoat used prior to AR coating, and even more important is whether or not there is a hardcoat on both sides of the lenses. It can be a major benefit if the same lab that AR coats your lenses also controls the surfacing process so that they can choose the best lens brands and hardcoats for their particular AR process.

Why do AR lenses get dirtier than normal lenses?

They don't! With normal lenses, reflections tend to hide the dirt whereas with AR lenses, because they are so much more clear, it is easier to see the dirt. It is like an early detection system. A patient with normal lenses will typically walk around for a day or more at a time with dirty glasses that affect their sight due to diminished transmission or light dispersion caused by dirt that they don't notice. With AR lenses, the dirt is noticeable and causes the patient to clean their lenses more often resulting in better and safer vision. And, although the earlier generations of AR lenses were difficult to clean, the newest generations are far easier to care for than ever before. ■

Recent Advancements in AR Quality

New Generation Super Scratch-Resistant AR

During the past 10 years, most issues associated with AR adhesion have been solved and AR developers have turned their attention towards increasing abrasion resistance. Numerous new brands have been introduced during the past 3 years that boast of 2 to 3-fold increases in scratch-resistance. Increased hardness is achieved through the application of specially designed hardcoat prior to AR coating with a traditional AR stack, or through the introduction of new generation harder AR stacks on top of traditional hardcoat. All of these new methods and brands result in superior quality AR and are contributing to the increased growth rate of anti-reflective lenses.

Sample of New Generation AR Stack

Quality Control and Understanding Plastics

Ten years ago, most hardcoats were designed strictly for hardness or tintability, and AR compatibility was not considered. Fortunately, this has changed dramatically and most hardcoats, especially UV cured backside spin coatings, are now being developed with AR compatibility as the overriding performance criteria. In addition, most AR coatings 10 years ago were applied by custom coating houses that had nothing to do with the manufacturing or surfacing of a lens. In many cases, custom coating houses had no control over the lens or hardcoat brands being sent to them nor in the surfacing practices used on the lenses prior to AR coating. Without knowledge of these factors, custom coating facilities faced a situation where they had to treat all lenses the same and therefore had to compromise quality practices. Today, on the other hand, most AR coatings are applied in or next to the same lab that manufactured and/or surfaced the lenses; this adds a great amount of control over the ultimate quality an AR lab can achieve. Labs can choose the best hardcoat brands and can also optimize their surfacing practices, back-side coating practices and actual AR process to acheive the best quality final product.

Advancements in Hydrophobic Topcoating

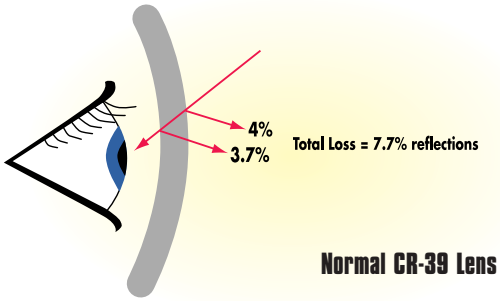
Hydrophobic topcoating is a thin organic polymer sealing coating applied as the final layer of an AR coating stack. Some are applied inside of the AR vacuum chamber, while others are applied via a separate process after AR coating. Numerous new polymers have been introduced during the past couple of years (one as recently as July 2002) that substantially increase the chemical resistance, repellency, abrasion resistance and ease of cleaning of AR coating. Most AR coatings produced today are as easy to clean as normal lenses.

Easy Care Hydrophobic topcoating makes today's AR lenses as easy to clean as normal lenses

How does AR coating work?

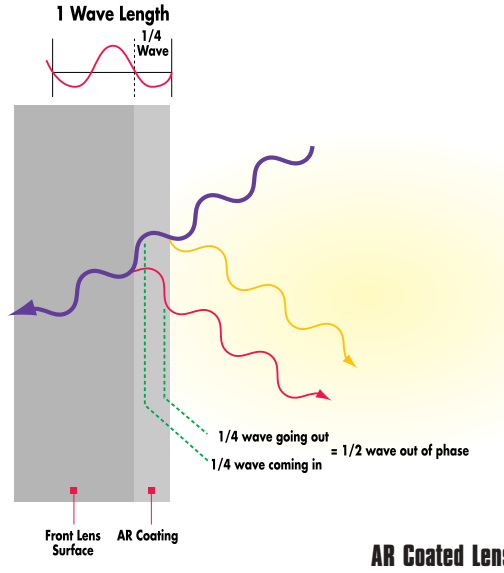
The basic concept for how anti-reflective coatings work is the "optical interference model". Each coating layer in the AR stack combines with previous layers to cancel out a broad range of light waves by introducing opposite, or destructive, waves that are out of phase. Thus, reflective properties of that range of light are neutralized.

By applying the principle of optical interference, we are able to increase light transmission to nearly 99% in most cases. The result is a reduction of reflections over a broad range of wavelengths…and clear, crisp vision for your patients!



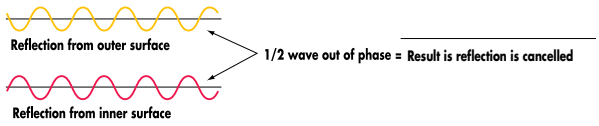
Standard Lens without AR

Standard, uncoated lenses can decrease light transmission by up to 15% of available light. This is caused by visible reflections on the front and back surface of the lens, as well as internal reflections. The higher the refractive index of lens material, the greater incidence of reflections and glare.



Destructive Interference Model

By causing the reflection from the second surface to be exactly 1/2 wave length out of phase from the reflection from the first surface, an AR coating causes the two reflections to cancel each other out, eliminating reflection.



Reality

The above depiction of how an AR coating works is an extremely simplified model. In reality, AR is not a single layer coating (which would only eliminate reflections in a small portion of the visible light spectrum), but rather a stack comprised of 4 to11 layers, creating a broadband AR to eliminate reflections across the entire visible light spectrum. In addition, light enters a lens from many different directions (incidents) and there is a high occurrence of inner surface reflections. Taking all of these factors into consideration, an AR coating stack design is created using a series of very complicated mathematical equations. For more information on the complexities of AR designs, visit www.opticiansnet.com (recent articles, "Reflections on The Web") or other websites listed on the back page of this guide.

How is AR coating applied?

Welcome to Star Wars...
electron beams, nanometers and ion guns.

The anti-reflective process takes place in a specially designed coating lab, through a series of steps taking anywhere from 4 to 10 hours. A truly effective AR process incorporates the entire laboratory...from surfacing to coating to finishing. It must begin in the most pristine of conditions to be successful. The environment must be clean and dust-free with a positive air-flow. After lenses are cleaned, they are placed inside of a vacuum chamber and microscopically thin layers of low, medium and high index materials are alternately applied in succession to both the front and back lens surfaces. Computer technology controls the process with extreme precision so that each layer is accurately applied. The following 6 steps demonstrate a typical AR application process.

To better understand the precision with which this process must take place, let's put it into perspective...the thickness of an AR coating is equivalent to 1/5,000th width of a human hair!

1 | Hardcoating After casting or surfacing, an important step is for all lenses to receive a scratch-resistant hardcoat prior to AR coating. The hardcoat can be applied using a thermally cured dipcoating system, or via a process as simple as UV cured spincoating.

2 | Hand Cleaning Lenses are individually hand cleaned to remove any remaining ink markings, dirt and debris.

3 | Ultrasonic Cleaning Lenses travel robotically through a cleansing process, alternating between tanks of detergent, tap water and deionized water. A slow-lift feature from the final tank allows lenses to dry with no residue.

4 | Degassing Lenses are baked in a degassing oven to remove all internal moisture and provide optimal conditions for successful AR coating application. The lens substrate determines oven temperatures, varying from 50C to 75C, as well as processing time, varying accordingly from 1 to 4 hours.

5 | Inspection Hand inspection assures optimal surface preparation prior to the AR process.

Overview

Physical Vapor Deposition Vacuum Chamber

Rotating Dome – Holds 30 to 200 lenses which have been placed into specially designed holding rings.

Quartz Crystal Monitor – Precisely measures the thickness of each metal oxide layer.

Vacuum Pumps – Turbo or diffusion pumps create a vacuum of approximately 10^{-6} mbar of pressure.

Electron Beam Gun – Evaporates various metal oxide chemicals inside a copper crucible. Creates a plume shaped vapor cloud of each chemical which then deposits on the lens surfaces.

Ion Source – Emits a field of charged electrons which clean and etch the lens surfaces prior to coating and can assist in layer densification during coating.

Shutter – Opens and closes to allow or stop physical vapor deposition.

6 | Vacuum Coating Lenses are loaded into a rotating dome and various low, medium and high index inorganic chemicals are loaded into the electron beam gun. The chamber is sealed and vacuum pumps establish the prescribed vacuum pressure. Various low, medium and high index chemical layers are evaporated from the electron beam gun at approximately 2000C and are deposited, one layer at a time, until the AR stack is complete. Finally, the hydrophobic topcoating is applied. The total process takes approximately 90 minutes. Lenses are then removed, inspected and forwarded to the lab finishing department.