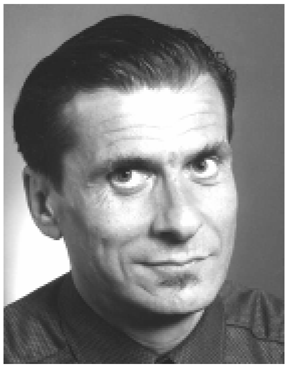
# A technical question or just a matter of personal preferences?

# *Matte vs. glossy displays*

*by Michael E. Becker*



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## Annoying reflections from our computer monitor – we had to live with them!

In the late 1990s, ISO 9241-7 for the first time addressed annoying and disturbing facts under which many computer users have been suffering for quite some time during their daily work in front of a visual display terminal (i.e. computer monitor): reflections from ambient light sources in the display screen which in those days used to be CRT monitors in most cases.

> *ISO 9241-7:1998* ***Introduction:*** *Visual display terminals (VDTs) are subject to reflections of environmental luminance and illuminance from the display device surfaces. Under some conditions, the reflections become disturbing to the user and affect both comfort and task performance. The objective of this part of ISO 9241 is to maintain usable and acceptable VDT image quality in luminous environments that can cause reflections from the screen.*
>
> This part of ISO 9241 contains requirements and methods for measurement of the image quality of VDTs used in luminous environments that can cause specular and diffuse reflections from the screen.

These reflections, as shown in *Figures 1 and 2* on the next page, have three negative effects: (1) they reduce the contrast of the displayed visual information by adding (reflected) luminance to the emitted luminance thus reducing the contrast, (2) reflected white light reduces the saturation of displayed colors (bleaching), and (3) distinct images of light sources reflected in the screen cause the human visual system to focus on those images which usually are at a much farther distance than the information shown on the screen. This competition between two images that can be focused may cause headache and other severe disturbances.

When computer monitors with LCDs started to become affordable in the second half of the 1990s, users experienced the work with an LCD monitor as a big improvement in terms of workplace ergonomics. The main and directly obvious advantage of these monitors was the absence of that kind reflection that gave a distinct image of disturbing light sources in the environment (windows, lamps, luminaires, white blouse/shirt of user, etc.). Reflections of light sources now became visible only as fuzzy balls (or areas) that were brighter than the background of the display area.

***Figure 1** on the left**:** Railway timetable shown on a CRT display with an anti-reflection coated vandal-proof cover glass, exhibiting reflections from ambient light sources (sky, lamps). The visual information can only be read (though with very low contrast) in the regions with shadow. **Figure 2** on the right**:** A modern shiny TV screen (2008), based on OLED technology, showing reflections of ambient light in the mirror-like display surface*

(source: http://commons.wikimedia.org/wiki/Image:Sony_OLED_TV_XEL-1.JPG)

***Figure 3:** Visual information in the presence of reflections with glossy (left) and matte surface (right). The arrows indicate the position of the light source (fluorescent tube). While the light source is distinctly visible in the part of the display with the smooth surface (yellow arrow in the left half), it can only be noticed as a fuzzy area that is somewhat brighter than the surroundings (yellow arrow in the right half).*

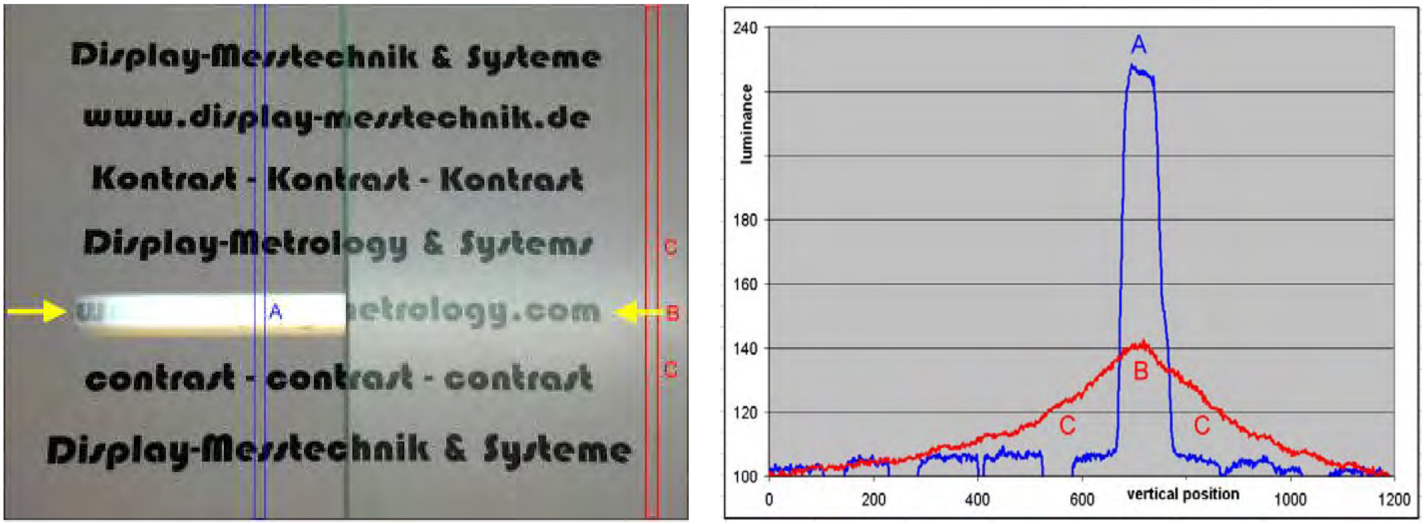


***Figure 4:*** *Vertical intensity (luminance) profiles of the photo of Figure 3 showing the peak A of the light source reflected in the smooth surface and the reflected luminance B which is considerably reduced by the scattering of the surface with micro-structures in the right half.*

The obvious difference between reflections of ambient light sources in a CRT monitor and an LCD monitor is illustrated in *Figure 3*. The left part of the photo shown in *Figure 3* corresponds to the flat, polished surface of a CRT screen; the right part corresponds to the scattering anti-glare (AG) layer of an LCD monitor.

The matte light scattering surface of LCD monitors used to have two effects: (1) an ambient light source reflected in the screen is not perceived as a clear image (left side), but rather as a fuzzy area with increased luminance (right side), and, (2) while the reflected luminance turns the visual information in the specular direction unreadable in the case of the glossy surface (left side, “disability glare”), the contrast of the text on the right is reduced but the displayed visual information can still be recognized without problems.

The scattering AG layer reduces the amount of light reflected in the specular direction thus removing disability glare, but at the same time the contrast in the vicinity of the specular direction (i.e. above and below the vertical position of the arrows in *Figure 3*) is reduced by what is called “veiling glare”, i.e. a certain amount of reflected luminance outside the specular direction decreasing with angular distance as shown in *Figure 4* (right diagram). This added reflected luminance from usually white light sources (e.g. daylight, room illumination) not only reduces the contrast to a certain extent, it also reduces the saturation of colors displayed on the screen.

Definition: diffusion, scattering: process by which the spatial distribution of a beam of radiation is changed in many directions when it is deviated by a surface or by a medium, without change of frequency of its monochromatic components.

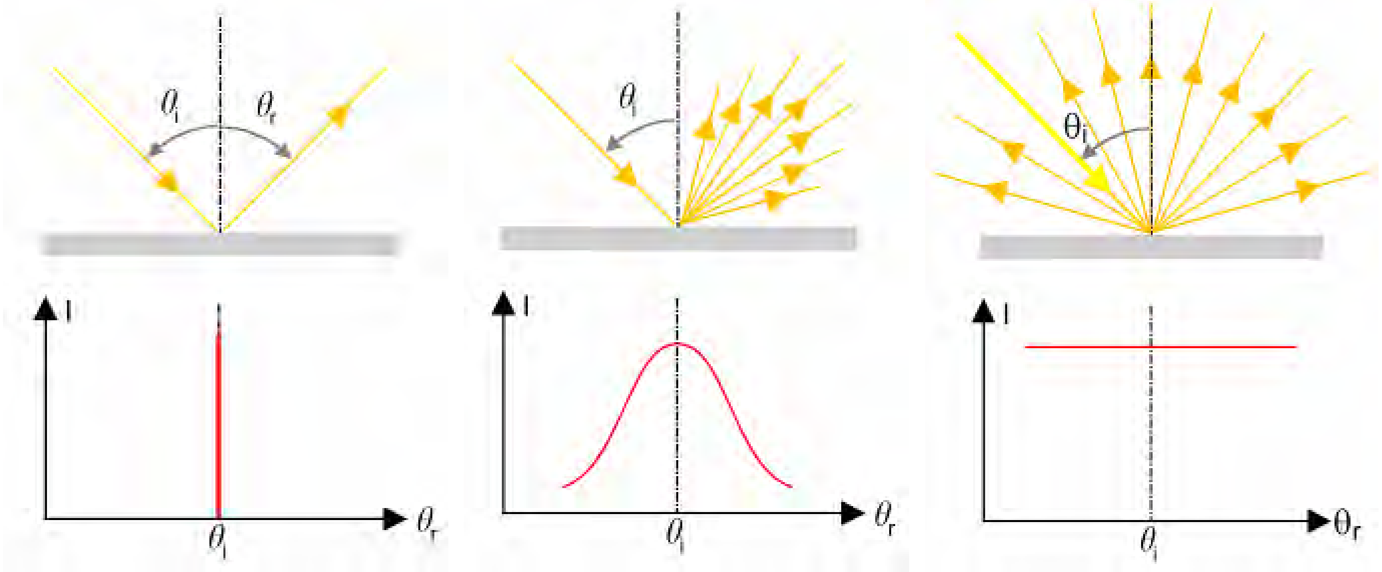
CIE No17.4-1987: International lighting vocabulary, 4th ed. (Joint publication IEC/CIE)

## Basic types of light reflection

- **Specular reflection:** a perfectly smooth surface (mirror) reflects incoming beams of light in such a way that the angle of inclination of the reflected beam, θr, is exactly the same as the angle of the incident beam, θi.
- **Hazy reflection:** micro-structures on the surface scatter the incident light beam into directions that do not coincide with the specular direction. The radiant power of the incident beam is distributed among all reflected beams, and the maximum of power is usually reflected in the specular direction. Width and height of the bell-

shaped curve in *Figure 5* (center) depend on details of the surface (micro)-topography. The transition from specular to hazy (and vice versa) can be observed when a mirror is being covered with condensing steam (fogging) or when the fogging slowly disappears and distinct images start to form again.

- **Lambertian reflection:** this type of reflection represents an extreme case, since all incident light is scattered into the hemisphere above the surface with the luminance being the same for all directions (isotropic directional distribution). Plain white paper for photocopiers or printers is a good example for a Lambertian diffuse reflector. It is perceived as equally bright from all directions of observation.



*Specular, mirror like reflection. The inclination of the reflected beam is identical to the inclination of the incident beam.*

*Reflection haze. The incident light beam is scattered about the specular direction. The intensity of reflection in the specular direction is reduced.*

*Ideal (Lambertian) scattering of the incident beam. The reflected intensity (luminance) is constant for all angles of inclination.*

***Figure 5**: Basic types of reflection – specular (mirror like, left), hazy (center) and Lambertian diffuse (right). The geometry is shown in the upper part, the intensity versus angle of inclination of a detector is shown in the lower part of the diagrams.*

## Reducing reflections

There are two ways to reduce reflections from surfaces: by scattering micro-structures that diffuse the incoming light into a range of directions (and out of the specular direction) or by stacks of smooth dielectric layers with their thickness and refractive indices set to cancel reflections by destructive interference.

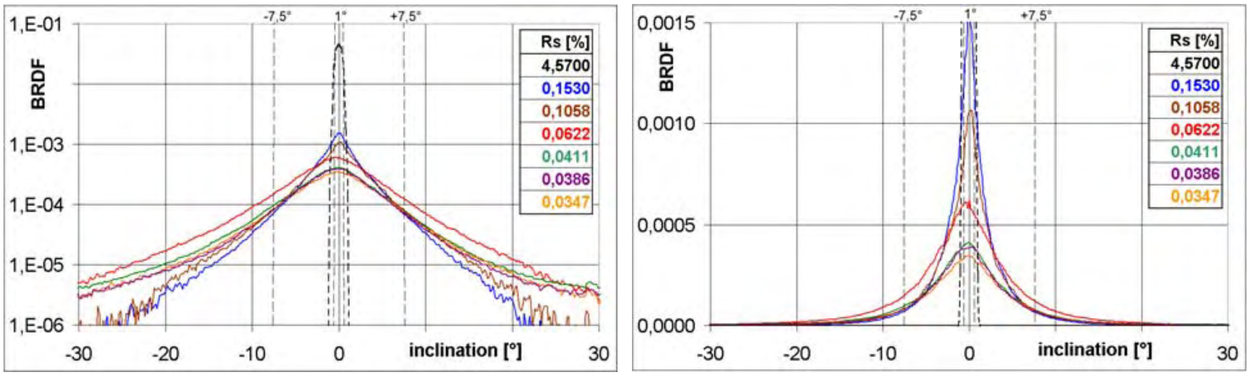


***Figure 6**: Anti-glare coatings*

*Figure 6* shows BRDFs of a variety of typical LCD computer monitors (logarithmic and linear scaling) with listing of specular reflectance values, $R_{S1}$. The narrow peak in the center is the BRDF of a black glass mirror with $R_{S1}$ = 4.57% used as reference (and showing the system signature). Peak reflectance values as low as ~0.035% are realized by a combination of AG and AR coatings (conoscopic measurements, the angle of light incidence is 20°).

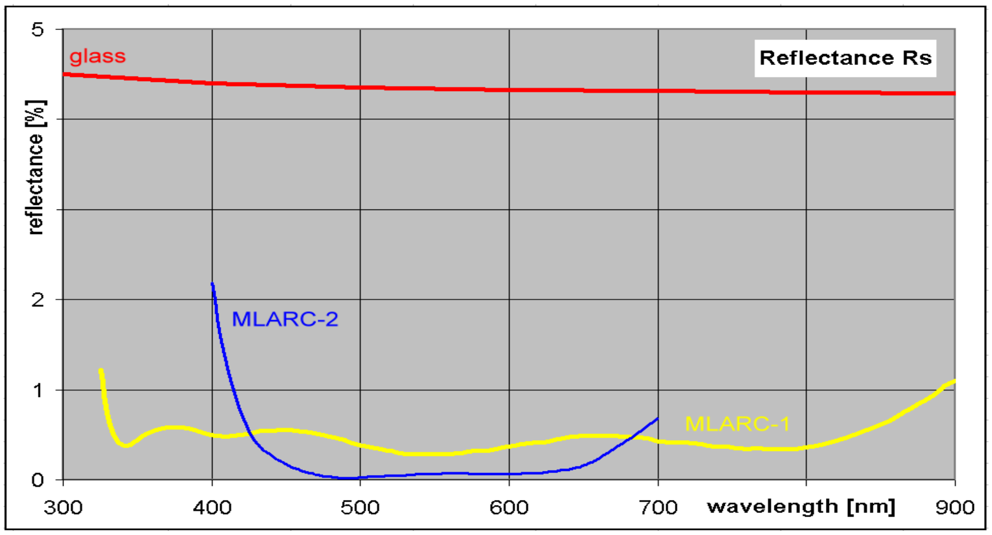


***Figure 7****: Anti-reflection coatings*

*Figure 7* shows specular reflectance spectra of two typical dielectric multilayer anti-reflection coatings (MLARC) measured at 10° inclination. One is optimized for a wide wavelength range (MLARC-1); the other is optimized for minimum reflectance at 500nm (MLARC-2). The average reflectance in the range 400–700nm is 0.425% (MLARC-1) and 0.245% (MLARC-2). This is a reduction of about a factor of 10 to 20 with respect to the reflectance of the untreated glass (0,457%).

## CRT monitors with AG coating?

The question may arise, why such an effective treatment for reduction of reflections was not applied to CRT monitors. When a scattering layer is placed over well-defined visual information (e.g. the scaling of the ruler in *Figure 8*), the definition of the information (lateral contrast) decreases with increasing distance between the initially well-defined information and the scattering layer as illustrated in *Figure 8*.

In LCDs the visual information is generated in the LC layer, which is typically about 1mm away from the scattering AG coating on the front polarizer surface. In CRT displays however, the front glass is thick (10-30mm, depending on the size of the tube) to withstand the atmospheric pressure. The visual information is generated by activation of the phosphors that are coated to the inner side of the CRT faceplate via a scanning electron beam.

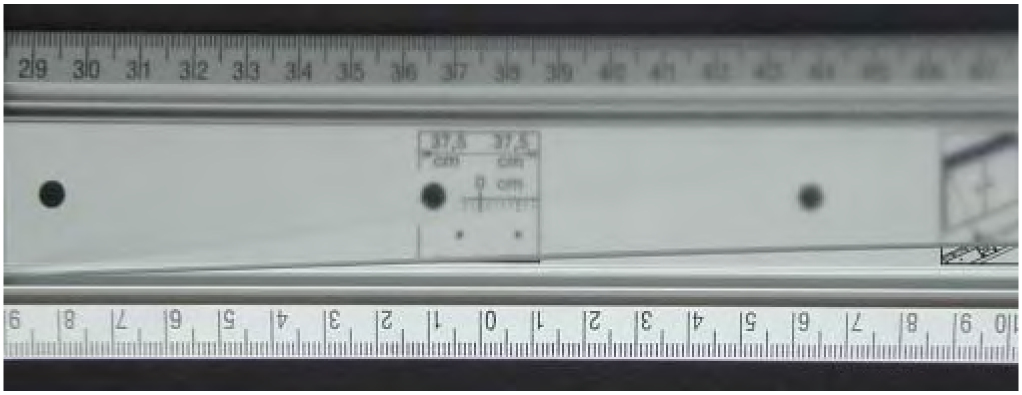


***Figure 8****: The blur induced by a scattering layer (matte glass) increases with the distance between the visual information (ruler scaling) and the scattering layer. The scattering layer is close to the ruler surface on the left side and the distance increases to the right, as does the blur. The condition shown in the upper left corner represents an LCD monitor (scattering layer close to the original visual information) while the condition in the upper right corner represents the blurring that would occur in a CRT monitor with the same scattering AG coating, but at an increased distance from the original visual information (thick faceplate).*

It is the distance between the original visual information and the location of the scattering AG layer, in the CRT case given by the thickness of the faceplate, that would either blur the displayed information at the same time as reflections are reduced, or the degree of scattering would have to be decreased that much (to avoid blurring) that reflections are not sufficiently reduced. This conflict between image blurring and reduction of reflected light made AG coatings much less effective for CRTs than for LCD screens.

An alternative way to reduce reflections from surfaces uses a stack of smooth dielectric layers with different indices of refraction (usually coated by vacuum processes) to realize destructive interference and thus a reduction of the intensity reflected light (see e.g. http://en.wikipedia.org/wiki/Anti-reflective_coating). While an untreated glass-air interface provides reflections between 4% and 100% (depending on the angle of incidence), anti-reflection coatings can reduce the reflectance from e.g. 4% to 0.4% and below, depending on the efforts involved (i.e. number of dielectric layers).

## Most work is not done in a dark room

Unfortunately, the contrast, being the major measure for the visual performance of a visual display screen and listed in technical specifications of display screens, is measured under dark room conditions while the actual work is (almost) never carried out in a completely dark environment. Ambient light reflected from the display surface reduces contrast, making the displayed information harder to recognize and decreases the saturation of displayed colors. In surrounds with non-zero illuminance it is the reflectivity of a display screen that determines the contrast of the visual information and thus the usability for e.g. computer work. The reflectance characteristics of a display screen consequently define the level of usability and ergonomic performance of display screens to a large extend.

In most working conditions, even when the work is done with mobile computers, the location of light sources that may be origins of reflections with respect to the monitor cannot be controlled in such a way that it would be possible to completely exclude these unwanted reflections. To a certain extent, rotation of the monitor and adjustment of its tilt angle (i.e. angle of inclination) may help to improve the situation, but as soon as the user is wearing a white blouse or a white shirt, this approach offers quite limited improvements.

**Performance of glossy & matte display screens in bright surrounds**

| | **Glossy display surface** | **Matte display surface** |
|---|---|---|
| **Distinctness of image (DOI)/image definition** | No scattering and thus no reduction of definition (distinctness) of the presented visual information (unless provided by fingerprints!). | Optimization of scattering for reduction of reflections vs. definition (distinctness) of presented visual information provides excellent results. Even the black matrix of the LCD screen can usually be distinctly recognized. |
| **Contrast/colors** | Glare and bleaching of colors in the specular direction with respect to ambient light sources.<br>High contrast and saturated colors outside the specular direction.<br>Large area light sources (e.g. sky, bright walls, white blouses, shirts) are hard to get out of the specular direction. | Some reduction of contrast and color saturation in and close to the specular direction, but overall better visual performance.<br>No distinct images of light sources cause focusing conflicts. |

**Conclusion:** In a dark environment the distinctness of image and the saturation of colors of glossy screens might be superior, even though it remains to be proven that the difference with respect to a well-designed AG coating is noticeable at all (and relevant for the task). In illuminated surrounds however, light sources in the specular direction to the user can be annoying and disturbing up to the point of disability-glare. If the display screen can be rotated and tilted to avoid specular sources, contrast and color saturation are slightly better than in the case of AG coated screens. This however is not possible in many cases (white blouse/shirt of user!).

## Glossy displays – a clever marketing campaign

Sometime around 2004 computer monitor manufacturers, especially manufacturers of mobile computers, were looking for new distinguishing features to promote the sales of their products. It was in those days that some marketing specialists started to provide arguments supposed to support the functional superiority of glossy display screens.

> "Glossy displays create more saturated colors, deeper blacks, brighter whites, and are sharper than traditional matte displays. This makes these types of displays more appropriate for viewing photos, watching movies, or even just general computer usage such as web browsing. Also, in extremely bright conditions where no direct light is facing the screen, such as outdoors, glossy displays can become more readable than matte displays because they don't disperse the light around the screen (which would render a matte screen washed out)." Source: http://en.wikipedia.org/wiki/Glossy_display

This paragraph illustrates the seductive mixture of almost true facts (or at least assertions that sound reasonable to the committed layperson) and fairy tales that are used to lure the customer to buy ergonomically inferior products and still be proud about it.

But marketing never sleeps. Since many customers remain unsatisfied with the usability of glossy screens in uncontrolled environments, they are able now to buy ergonomically improved (matte!) display screens (actually the good old AG coated versions), but now it is a distinguishing feature in the world of portable computers and you have to pay some extra for that ingenious special feature.

## The psychology of quality rating

Since the last few years have shown that a large number of customers are immune to functional features and advantages (i.e. the improved usability of matte display screens in non-dark surroundings), the question arises how this situation could be maintained. Numerous personal observations (with accessories like cars, watches, jewelry, attire, etc.) support the thesis (my very personal one) that people can be classified according to their perception of quality: for some it is the polished, shiny, glossy stuff that represents value and top-quality; for others it's rather the reduced gloss and silky luster of matte surfaces and muted colors. So, the choice between glossy and matte is also a question of individual taste and preference and thus not negotiable.

## References and further reading:

- ASTM Standards on Color & Appearance Measurement
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- CIE No38-1977: Radiometric and photometric characteristics of materials and their measurement
- CIE No 44-1979: Absolute methods for reflection measurements
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**Multilayer anti-reflection coatings:**

- M. Parish, et al, Information Display Magazine 2(1995), p. 10
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