

High-purity Makrolon® lights up LCD monitors

Large-format TV screens



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LCD TV

Flat-screen TVs have found their way into many living rooms in the last two or three years, but conventional plastics have stunted their growth so far, as the thin diffuser sheets used in their production have a tendency to warp. A research team from Bayer MaterialScience has now developed a high-purity grade of Makrolon® with outstanding optical properties that stays in shape even in oversized screens.



TV screens stretching as far as the eye can see: the room in building R 79 in Krefeld-Uerdingen where Dr. Claus Rüdiger and Dr. Gunther Stollwerck do their everyday work is packed full of high-tech equipment from the consumer electronics industry. But the two specialists are not TV addicts, they are more interested in the innards of modern flat-screen TV sets. On one of the tables, a dozen or so of the thin monitors – completely bare and without housings – stand carefully wrapped in plastic film, stacked up against each other like picture frames. Rüdiger is a chemist, Stollwerck a physicist, but their laboratory is more like an electronics workshop: a multitude of electrical components,

and shelves packed with small drawers, each carefully labeled "junctions", "resistors", "capacitors", etc. Together, the two men are occupied with getting large flat-screen panels to shine even more brightly than before.

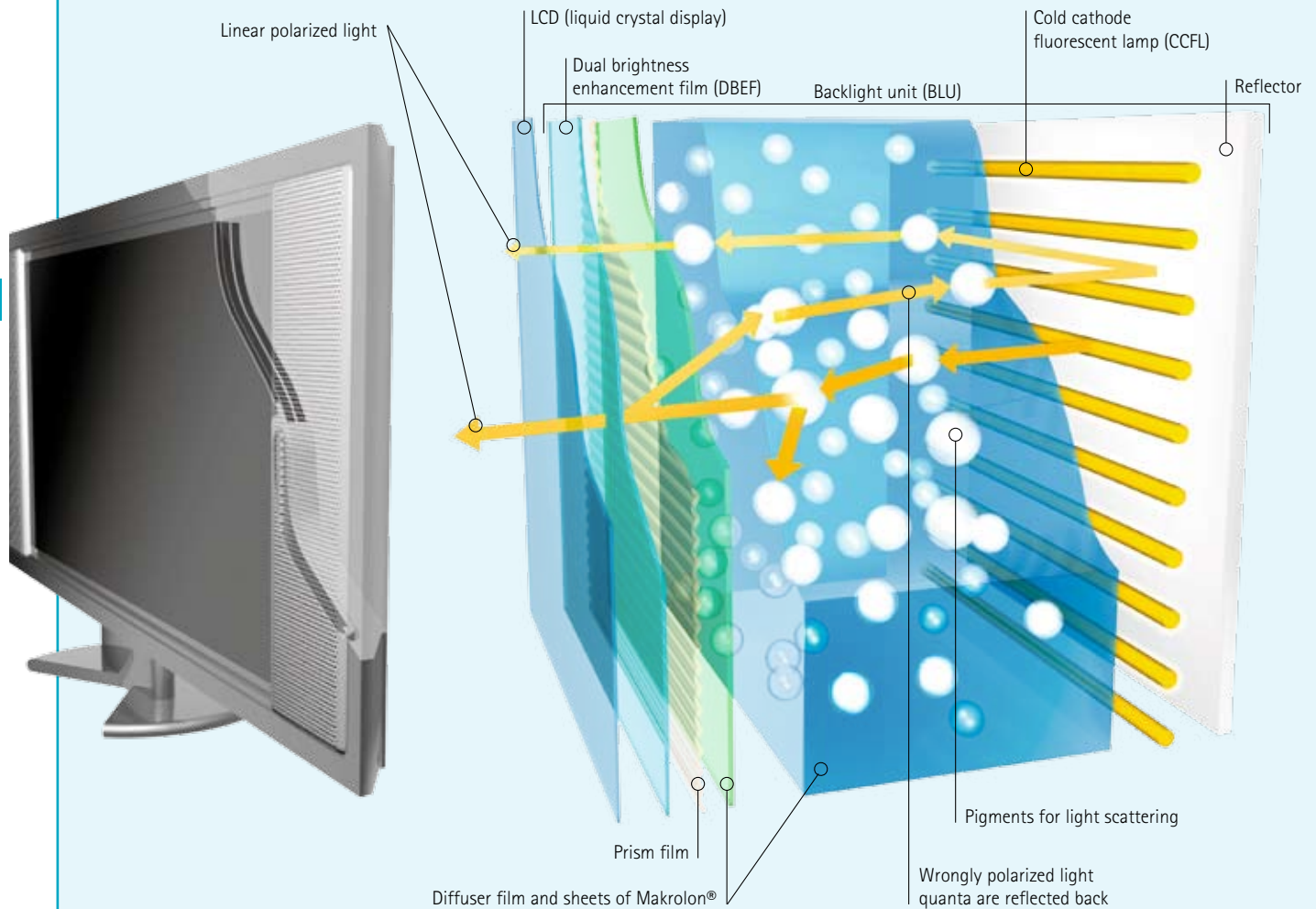
High-tech sandwich made of thin layers of plastic film

Stollwerck picks up a monitor and lays it thoughtfully on the laboratory desk. He then pulls on a pair of soft white gloves and begins to take it apart. In fact, the device on the table has very little in common with what we see in radio and TV stores because not only is the dark screen at the front missing, so is the

TVs in the spotlight: LCD TVs are booming and new materials are needed. Bayer technicians like Andreas Lyding are now working on special Makrolon® blends to make flat screens even brighter.



The light behind the screen



To conjure up an evenly bright and brilliant picture on the screen of an LCD monitor, a large number of components and optical layers are needed. In simplified terms, the screen can be subdivided into two components: the backlight unit in which the light is generated and modified, and the LCD display, which contains red, green and blue color filters and liquid crystals that are alternately activated by fine electric impulses and allow the light to pass through. This results in a moving color TV picture. In the rear part of the backlight unit are several fluorescent lamps no more than a few millimeters thick. Light reflected backwards is thrown forward by a reflector on the inside of the housing. It then passes through a number of sheets of plastic film that optimize the light yield. Initially, the light migrates through a diffuser sheet and a thinner diffuser film that scatter it evenly and obliterate the stripe pattern of the fluorescent tubes. This results in homogeneous illumination of the screen.

Then comes a prism-shaped film, the surface of which is structured in such a way that incident light coming from various directions is reflected directly forward in the direction of the LCD display. Subsequently, the light impacts what is known as the Dual Brightness Enhancement Film (DBEF), which allows only linear polarized light to pass through. This is important because the crystals in the LCD display can only utilize exactly polarized light. Light with a different orientation is reflected by the DBEF back to the reflector. This reflects it again forward to the DBEF. The trick is that during the reflection back and forth, some of the light quanta change their polarization so that they can pass through the DBEF at the next attempt. The DBEF thus increases the yield of correctly polarized light and enhances the efficiency of the backlight unit. Finally, the light passes the LCD display and the color picture appears on the screen.

actual liquid crystal display (LCD) screen with its electronics. What Stollwerck has in front of him is what is called a "backlight unit" (BLU) – the rear part of an LCD TV that provides the light. The backlight unit is a high-tech sandwich made up of thin layers of plastic film and a diffuser sheet. Stollwerck pulls off one layer after the other – four milky white, semi-transparent sheets, the thickest of which is no more than 2 mm. Then the rear wall of the monitor is exposed – a white, highly reflective plastic dish in which 16 pencil-thin fluorescent tubes are inserted. "If the fluorescent tubes were mounted directly behind the LCD monitor, we would get a TV picture with very uneven brightness. The tubes would shine through as bright stripes," explains Rüdiger.

Bright screens through polarized light

This means the light has to be scattered beforehand – which is where the diffuser sheet comes in. The various film layers also bundle and polarize the light so that, wherever possible, every iota of it passes directly through the

LCD to the eye of the viewer. The tricky thing about it is that the homogenizing diffuser plate constitutes an optical obstacle and absorbs light. The weakening of the light from this component must therefore be minimal, and this is precisely what the two research scientists are working on. Rüdiger develops the diffuser sheets, Stollwerck tests them. The LCD team has recently been strengthened by physicist Dr. Günther Walze, who is using optical simulations to research the next generation of diffuser sheets. Liaising closely with the diffuser sheet team, Klaus Meier and Dr. Heinz Pudleiner are developing suitable types of diffuser film.

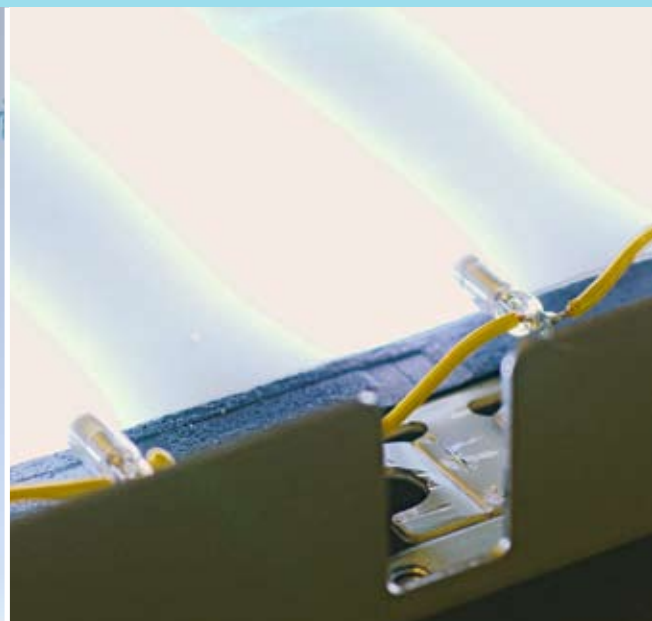
Four years ago, the researchers would never have dreamed they would some day be involved with TV screens, because Rüdiger had always been involved with plastics in other ways. He is a specialist for Makrolon®, a highly versatile Bayer polycarbonate that has found its way into numerous applications since its invention in 1953. In fact, Rüdiger has created several new products from it: by varying the type of additive, he invented transparent screens for protecting machinery, and

he also came up with bright, transparent sheets for architectural design. The roof of the nearby railway station in Krefeld is also covered with Makrolon®. Several thousand miniature plastic panels are constantly being tested in his laboratory or outdoors in weathering tests. Some of them have even found their way to Florida, where the material has to resist ten years of tropical heat without yellowing or becoming brittle.

Heat-resistant Makrolon® for large screen diagonals

In 2003, a completely different kind of specimen arrived at his laboratory. A colleague from Marketing had sent him a piece of film made of the plastic PMMA (polymethylmethacrylate) from the backlight unit of a flat panel. The question accompanying it was just as brief as it was to the point: "Can we do this with Makrolon, too?" PMMA has been long established in the production of LCD monitors, for example in computers. It is used for the diffuser sheets or panels in the BLU. But as the size of LCD TVs continues to grow, PMMA is slowly reaching its limits, because the larger the screen,

Focusing on brightness: chemist Dr. Claus Rüdiger (left) and physicist Dr. Gunther Stollwerck in the Laboratory for Display Technology, Lighting and Optics are working on new blends of Makrolon® that will help to raise the light yield of the backlight units (details in the picture on the right) of LCD TV sets.



the greater the tendency of the sheet to warp. The result is that troublesome shadows are produced on the monitor and the brightness distribution is no longer uniform. Experts speak of "inadequate dimensional stability". The problem is intensified by the high temperatures of up to 80 °C that are generated in the BLU. There is now general agreement that a diagonal screen size of 42" is the limit for PMMA, because anything larger than this and the screen manufacturers have a problem. Makrolon®, on the other hand, has much higher dimensional stability and can easily withstand temperatures of up to 120 ° C.

Ping-pong effect increases light yield

But back in 2003, nobody knew whether the polycarbonate would be able to satisfy the high optical specifications made on an LCD backlight. Rüdiger began testing various Makrolon® sheets from his collection and comparing them with PMMA. The first tests were disappointing. Although his standard Makrolon® allowed just as much light through as

PMMA in some measurements (they both had a transmittance of just under 90 percent), if he placed a Makrolon® diffuser sheet beneath the film sandwich of the backlight unit, the brightness dropped drastically. Rüdiger and his colleagues soon recognized the cause: the function of all the film layers is based on the principle of light recycling. All undesirable light quanta are projected back to the reflector on the rear wall of the television, from where they are sent out on their journey again. During this optical back and forth, the light quanta are re-directed and can now, at the second attempt, pass through the system unhindered.

However, if the light flies back and forth through the Makrolon® diffuser sheet several times, it gradually becomes weaker. In the first trials carried out by the Bayer research team, it dropped to 63 percent. This meant that Rüdiger had to improve the optical properties of the Makrolon®. This was exceedingly tricky because a diffuser film consists not only of pure Makrolon®, it also contains tiny pigments on which the light of the fluorescent tubes is scat-

tered. These pigments are invisible to the naked eye. Rüdiger and his team tested hundreds of different Makrolon® formulations, mixed in different scattering pigments, and repeatedly varied their particle size. However, the result remained disappointing – the brightness went up, but only to 80 percent of the PMMA value.

LCD TVs with Makrolon® are much brighter

It was then that Rüdiger took the decisive step: instead of testing previously known Makrolon® formulations, he this time opted for a special carbonate type "that had never been used before in this form." Once again, he had to vary the scattering pigments and change the formulation. But then it worked and the brightness jumped to 102 percent. That was the breakthrough. Rüdiger now had a dimensionally stable material that had even better optical properties than PMMA. Three years have passed since then.

In the meantime, through repeated optimization, Rüdiger has reached 105



Boom in flat screens

In 2006 for the first time, more LCD and plasma televisions were sold around the world than TV sets with a cathode ray tube. The flat panel displays are manufactured predominantly in Taiwan and South Korea, where the leading global producers operate what are currently the world's largest LCD screen manufacturing facilities. In the short to medium term, however, experts expect China to catch up at least with Taiwan and even overtake it as a major LCD producer.

percent. Consequently, flat screens made of polycarbonate are now shining out even more brightly than those made of PMMA. "We are one of the few manufacturers worldwide that can produce the tough polycarbonate in this quality."

Rüdiger and his colleagues now guard a whole number of diffuser formulations in their laboratories. The Makrolon® is produced in Map Ta Phut in Thailand and extruded into sheets at the Bayer subsidiary, Bayer Sheet Korea,

because Asia produces by far the most flat screens. From there, more and more new BLUs are reaching Germany. In Stollwerck's testing laboratory, these units are then covered with diffuser sheets made of Makrolon®. He tests to see whether the brightness data have improved thanks to Rüdiger's formulations. Depending on the number of lamps or the structure of the BLU, the optimum polycarbonate will always vary. Whether the diffuser sheet really does scatter the light homogeneously

and produce the desired brightness at the end of it all is tested in a measuring device the size of a washing machine – a creation from Stollwerck's colleague Andreas Lyding. A robot arm inside fitted with a light and color sensor scans the illuminated BLU according to a given pattern.

The next generation of diffuser sheets will contain hardly any scattering pigments but will guide the light specifically to the LCD display through a micro-surface structure. The structured diffuser sheets thus enhance design freedom and reduce costs at the same time. Bayer Sheet Korea already supplies two major TV manufacturers with the first generation of the new material and thus covers a large part of the market for LCD TVs. Says Rüdiger, "The future of Makrolon for LCD TVs looks very promising indeed."

www.displaysearch.com/free/presos.html

The link contains numerous presentations on the topic of LCD monitors for free download.

Greater light transmission wanted: an ever increasing number of new backlight units (picture left) are arriving at the Bayer research team's laboratory from Asia, where by far the most flat screens are produced. They are then covered with diffuser sheets made of Makrolon®. Andreas Lyding (right) checks the transparency of one of the sheets.

