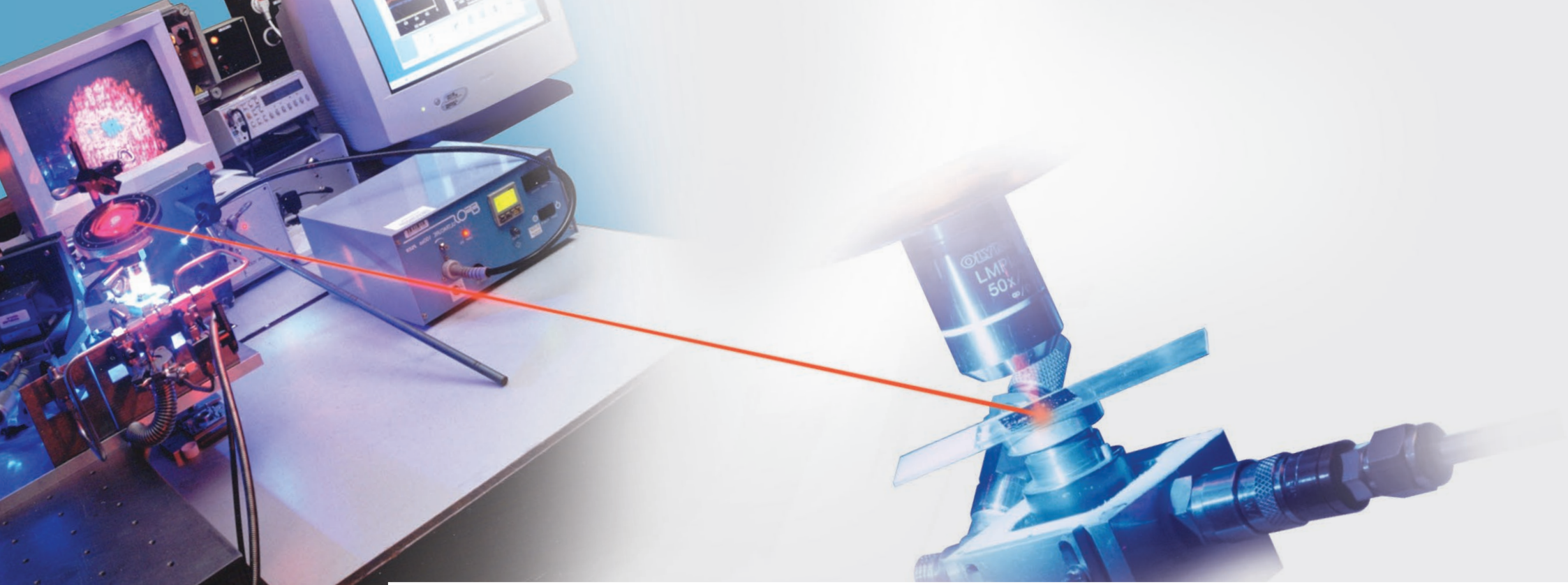

UV curing of optical pick-up lenses

A closer look with Raman spectroscopy

In cleanrooms various processes take place, such as lithography, baking and etching. These activities, but also outside air, can be the source of many gaseous contaminants. These form a potential health risk for people working in the cleanroom. By maintaining normal precautions in the cleanroom, health risks can be avoided effectively as concentrations of contaminants remain far below the MAC values. However, the contaminant level is not zero and the low concentrations present can still damage equipment and influence processes in the cleanroom.This application note describes the analytical method used for the detection of reactive contaminants, like ammonia and acid vapours.

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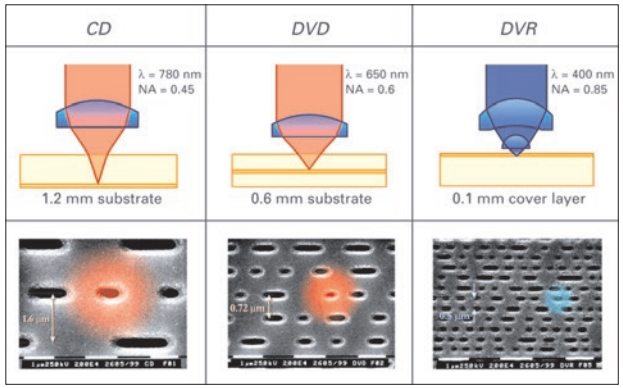


Fig. 1: Optical data storage possibilities.

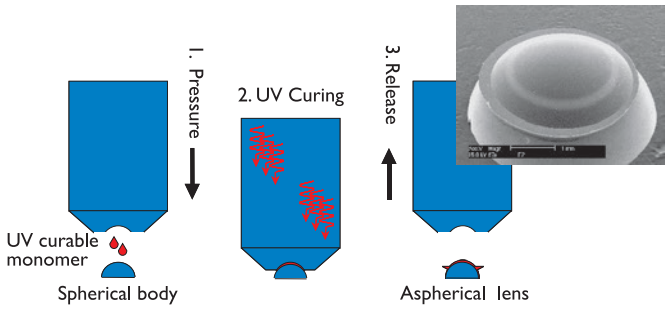


Fig. 2: The lens replication process and the final product (SEM-picture).

Digital video recording

The new standard for optical data storage is Digital Video Recording (DVR). It should allow storage capacities of more than 30 Gbytes (4 hrs of video) on a surface the size of standard CD. To write and read this much information, the size of the laser spot should be kept to a minimum. This means that blue laser diodes and special aspheric lenses have to be used (fig. 1). Such lenses can be made from spherical lenses of conventional optical glass by correcting them by a thin (1 to 30 micrometer thick) aspherical layer of a transparent polymer.

Lens replication

The application of a correcting polymer layer is a three-step procedure (fig. 2). A small droplet of monomer (lacquer) is applied on the surface of a glass lens. Subsequently, an aspherical mould is applied to shape the correction layer with nanometer precision. The layer is then exposed to UV radiation to obtain a solid and stable polymer (UV-curing), after which the mould can be released.

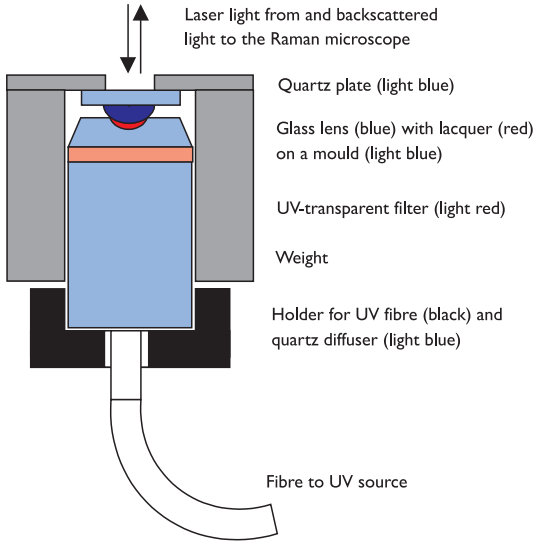
Raman spectroscopy

When laser light hits a surface, it gets reflected and scattered. Part of the light is scattered inelastically. The energy lost during the inelastic scattering contains chemical information about the irradiated material. This phenomenon forms the basis for Raman spectroscopy.

The energy transferred during scattering is typical for specific bonds in the material. This energy loss is normally translated to a wavenumber shift (cm^{-1}). An example: a typical carbon-carbon double bond will result in inelastically scattered light at 1600 cm^{-1} from the laser wavelength. The amount of light is indicative for the concentration of a functional group in which the bond is present.

When the material of interest is visible to the eye, it can be reached by laser light. At the same time, the inelastic scatter from an object in water or behind glass can be analyzed without removing it from its environment. This means for the UV curing reaction that Raman analysis can be performed inside an actual production set-up when an optical window is present through which the lacquer can be analyzed. As the lens is transparent, a set-up as described in fig. 3 can be used to analyze lens production.

Fig. 3: Production system for aspheric lenses.



The Raman spectra of the lacquer contain a large amount of information about the functional groups in the material that change during polymerization. Fig. 4 shows a part of the spectra, taken before and after UV curing. The clearest differences between the spectra before and after UV curing are seen in the Raman bands at 1386 cm^{-1}, 1622 cm^{-1} and 1704 cm^{-1}. These are linked to changes in the C=C and C=O bonds that occur as a result of conversion of methacrylate groups during the polymerization.

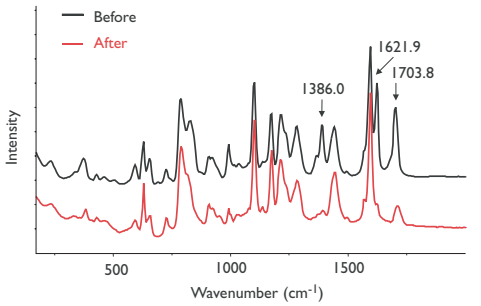


Fig. 4: Raman spectra before and after UV-curing. The position of characteristic Raman peaks is indicated.

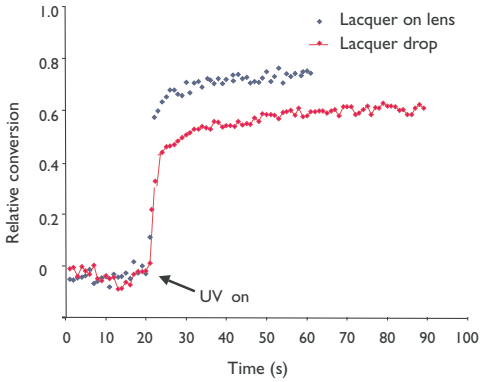


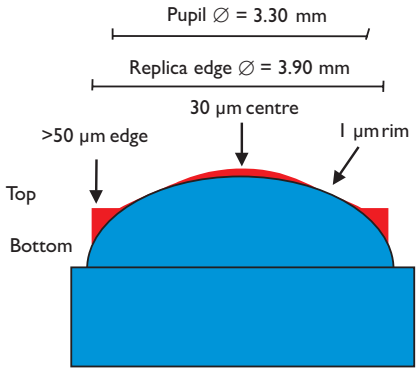
Fig. 5: Relative conversion of the monomer to polymer for a free drop and lacquer on a lens.

Reaction kinetics

A small drop of lacquer was UV cured on a lens in the set-up described in fig. 3. For comparison a drop of lacquer was cured in the same set-up without the lens present, leaving a large amount of free space around the drop. During the reaction a spectrum is recorded every 0.5 seconds. To obtain a clear indication of the conversion from monomer to polymer, the data is analyzed using a multivariate method that looks for changes in the spectrum that occur simultaneously. The relative conversion in time is shown in fig. 5 for both the free drop and the lacquer on the lens.

The reaction is too fast to follow the first part of the conversion during illumination, but the data clearly shows that the final degree of conversion is higher when the lens is present. This confirms that the actual production process cannot simply be studied on a free drop of lacquer. At the same time this example shows that the in-process analysis capability of Raman spectroscopy is very valuable.

Fig. 6: A description of the lens after photo-polymerization (polymer = red, glass = blue).



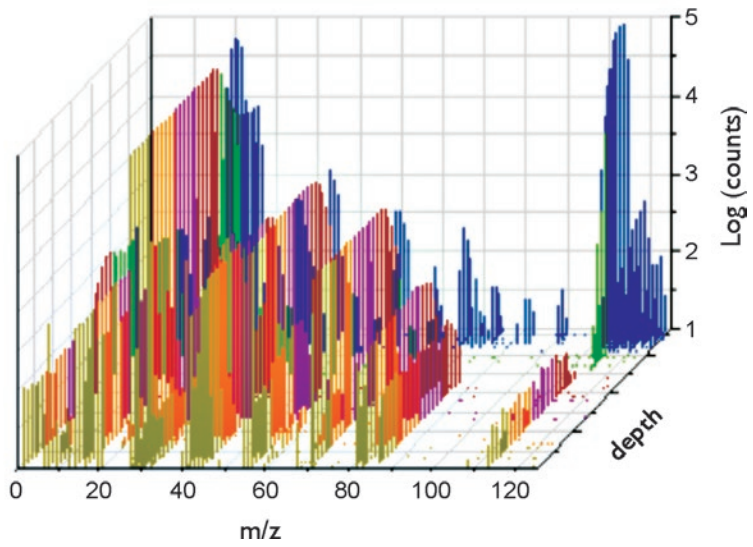


Fig. 4: Mass spectra obtained from the device structure, reconstructed from the recorded depth profile.

From the "raw" data it is also possible to reconstruct a high mass resolution spectrum at any depth. In this way information can be obtained about all elements including those that were not expected.

In figure 4, some reconstructed mass spectra are shown as a function of depth. Peaks from the device structure are easily recognized. At mass M=26.98 amu (atomic mass units), the Al peak is clearly visible. After prolonged sputtering, the ^{113}In and ^{115}In peaks (isotopes at mass 112.90 and 114.90 amu) appear in the spectrum.

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Application Note 11
August 2016

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