Microsc. Microanal. 28 (Suppl 1), 2022
doi:10.1017/S1431927622003853

Application of a Correlative fs-Laser Workflow for Fast and Easy Feature Access in Failure Analysis of Recycled Automotive Body Parts

Tim Schubert[1*], Timo Bernthaler[1], Torben Wulff[2], Ben Tordoff[2], Gerhard Schneider[1]

[1.] Aalen University – Materials Research Institute, Aalen, Baden-Wuerttemberg, Germany.
[2.] Carl Zeiss Microscopy GmbH, Oberkochen, Baden-Wuerttemberg, Germany.
* Corresponding author: Tim.Schubert@hs-aalen.de

In process development of recycling used automotive body parts into new high-performance parts, a variety of defects with different root causes may occur that have to be analyzed. Besides structural defects, which might influence application properties, also defects that inhibit a high-quality surface finish must be prevented and therefore analyzed thoroughly regarding their root cause.

The presented work outlines a correlative approach combining light- and electron-microscopy as well as Femtosecond (fs) Laser and Focused Ion Beam (FIB) preparation techniques to rapidly prepare large cross sections and reveal deeply buried features which lead to surface defects on in-development painted bumper parts made from recycled material.

After extensive aging tests under different temperature and humidity cycles, painted bumper parts manufactured from shredded old bumpers show sparsely distributed bulges of approx. 100 µm in size on the paint-surface which pose a significant quality flaw. To find the cause of the observed defects, a preparation method to specifically target the small defect locations has to be applied. Because of the small defect size standard materialographic preparation is not suitable so FIB preparation should be the method of choice. However, as the width of the defects expand the reasonable FIB cross section width and the cause of the defect is estimated to be in the recycled material which is covered by several lacquer layers, FIB preparation alone will take a lot of time and thus is also not efficient. Further it was observed that the surface defects are visible to the human eye and also in a light microscopic investigation but not in the electron microscope which makes locating the target region for cross section preparation difficult.

To overcome the described obstacles a correlative microscopy workflow was used for the investigation. First a light microscopic investigation was conducted to locate the surface defects and with a special software solution the precise locations of each defect where saved to the acquired image stack. Afterwards this image stack was loaded at the electron microscope and the sample was aligned with the LM images. With the LM image overlaid on the SEM live image the location of each defect could easily be found in the SEM and used for location specific cross section preparation. Figure 1 left shows the overlay of the fs-Laser prepared trench on the LM image of one of the found surface defects.

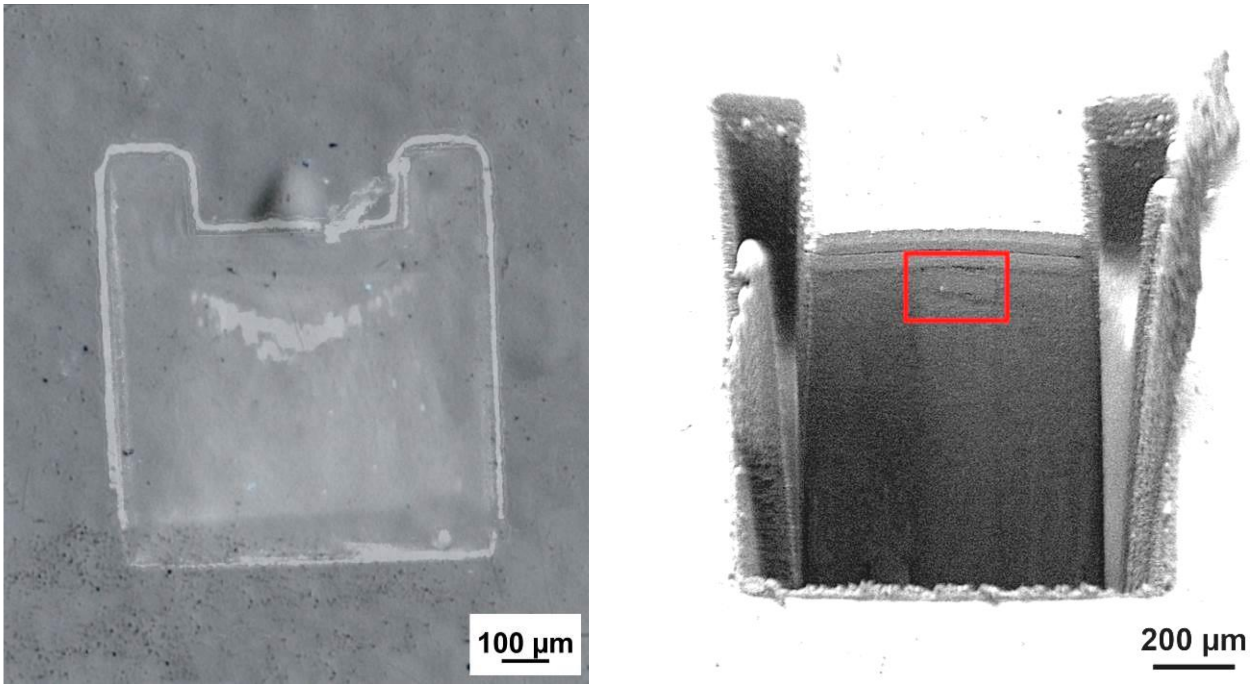

Figure 1. Left: LM image with SEM image overlay of fs-Laser trench shows precision of correlative microscopy approach; right: fs-Laser prepared cross section through surface defect shows peculiar feature just under the lacquer layers.

After relocating the defects in the SEM a location specific fs-Laser preparation was conducted. The advantage of fs-Laser preparation is the rapid material removal rate with minimal to no heat affection of the material due to the rapid energy input of the fs-Laser. Figure 1 right shows the resulting laser trench at the location of a surface defect. The cross section has a width of ~500 µm and a depth of > 800 µm. Already in the overview image a peculiar particle embedded in the base material right underneath the lacquer layers can be observed.

With a specifically developed recipe beforehand, the laser preparation time was < 1 minute and the resulting surface quality of the laser cut was already sufficient to clearly see the embedded unstructured particle in the base material (see figure 2 left) however, a FIB post-polishing was applied to get a more clear view of the microstructure surrounding the particle and to conduct a good quality EDS analysis of the area of interest.

https://doi.org/10.1017/S1431927622003853 Published online by Cambridge University Press

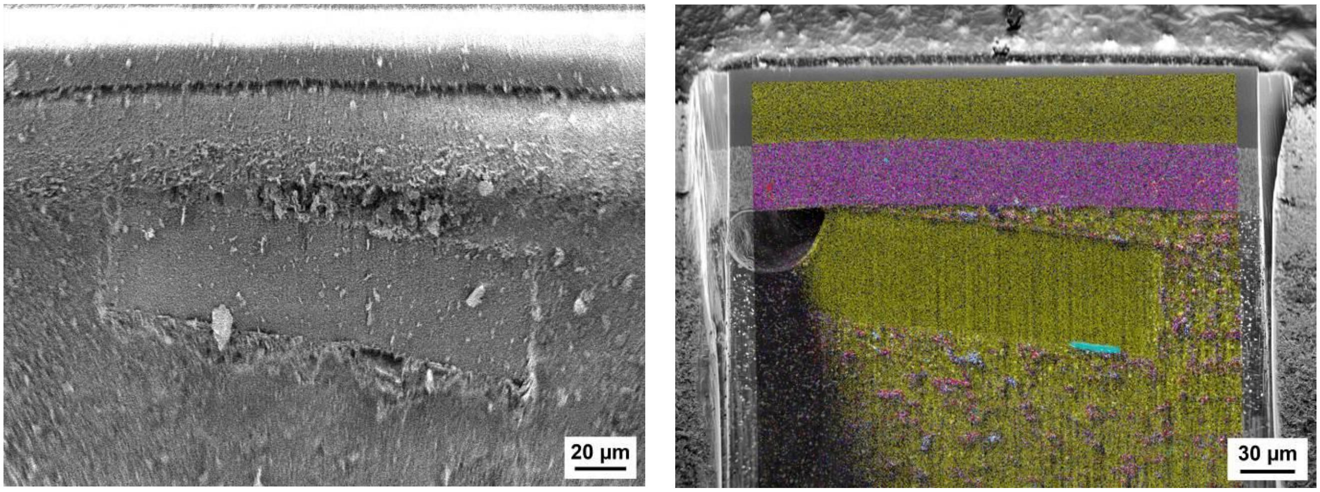

Figure 2. Left: Embedded unstructured particle underneath lacquer layers in laser prepared state; right: EDS elemental mapping on FIB post-polished cross section surface; yellow: C-intensity, blue: Al-intensity, pink: Ti-intensity, red: Si-intensity.

Figure 2 right shows the FIB polished cross section with an EDS elemental mapping overlay. Yellow represents the Carbon signal, pink represents a strong Titanium signal and blue shows a high Aluminum content. The unstructured foreign particle shows a high C-signal with an adhering Al-rich particle. The absent inner structure of the particle and the high C-signal as well as the solitaire adherent Al-particle indicates that the particle is a residue of a clear lacquer layer. Furthermore, a large cavity can be observed on the interface of the foreign particle and the surrounding base material (Figure 2 right).
The conclusion of the conducted investigation is that during recycling of old bumper material for new parts, the lacquer layers where not sufficiently removed before shredding and thus can be found sparsely distributed in the new material.

When a residual lacquer particle is coincidentally located on the surface of the new material right underneath the new lacquer layers a combination of humidity and temperature changes during aging tests might result in the formation of pores at the interface between plastic and residual lacquer particle due to weak adhesion. The resulting volume change then leads to the observed local bulging of the overlying lacquer layers.

The applied correlative workflow provides a fast and reliable way to investigate rare and sparsely distributed defects and with the addition of the fs-Laser to a FIB/SEM machine a rapid highly location specific preparation method is at hand. The presented workflow is not only suitable to investigate plastic parts in the automotive industry but has also shown great advantage for all sorts of materials.