ACOUSTIC MICROSCOPY INSPECTION OF GLASS REPAIR TECHNIQUES

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INTRODUCTION

Acoustic microscopy is a powerful ultrasonic technique for flaw detection and material characterization. The instrument usually consists of a piezoelectric transducer and a spherical focusing lens coupled to a surface with water. Generally, the instrument measures the amplitude of the interference of two acoustic signals, the specular reflection which travels along the lens axis between the transducer and the surface and the induced surface wave. The surface wave is generated when the lens is defocused and acoustic energy strikes at the critical angle. The generated wave travels along the surface and radiates energy into the couplant, some of which is detected by the transducer as shown in Figure 1. The amplitude of the interference of these two signals is then converted to an image [1].

Material flaws and changes in elastic properties affect the reflection coefficient and/or the surface wave velocity. This influences the interference amplitude and therefore, the brightness or contrast of the image. However, the strongest influence on the acoustic microscope images is the distance

![Figure 1](image-url)  
Figure 1 A defocused acoustic microscope lens showing the specular reflection and surface wave signal.
between the lens and material surface or "lift-off". The interference amplitude is maximized when the surface is in the focal plane of the instrument and decreases markedly as the lift-off is changed producing the well known V(z) curve. Therefore, surface topology can produce a large change in the contrast unrelated to material characteristics. Another lift-off related effect which can disrupt the image is due to surface tilt. Surface tilt produces strong interference fringes which can mask the subtler effects from flaws and material properties. Therefore, a smooth, level surface is required for a good image.

The samples investigated here (obtained from the Institute of New Materials at the University of Saarland) consist of a series of Vickers indentations made in float glass. Float glass refers to the manufacturing method used to create sheets of precise thickness for architectural applications [2]. Some of the Vickers indentations were filled with additional glass in an attempt to repair the indentation and some left empty to serve as a control. The objective was to determine the feasibility of using acoustic microscopy to distinguish between the the repaired and empty indentations.

IMAGES OF VICKERS INDENTATIONS

A Leitz commercial scanning acoustic microscope with a 1 GHz lens was used to produce the following images of the Vickers indentations in glass. The lens diameter and focal length were 123 and 80 μm, respectively. The images here are 200 x 200 μm² in size and were made at a defocus of about 6 μm (± a few micrometers).

Empty Indentations

Figure 2 shows images of two different empty Vickers indentations on glass. The distinguishing features of these images is the sharpness of the details and the degree of the contrast changes within the indentation. Bright areas around the outer edges of the indentations correspond to surfaces at the focal point of the instrument. Dark regions correspond to surfaces above or below the focal point or where acoustic energy cannot return to the lens. For instance, the centers are dark since this region is below the focal point while the cracks emanating from the corners are dark since Rayleigh waves are reflected from the abrupt discontinuities. The interference fringes associated with the cracks are not due to surface tilt but are due to the interference between the initial and reflected Rayleigh waves. By lowering the lens, it was possible to focus on deeper regions of the indentations. This is indicative of an empty indentation as compared to the acoustic microscope images of the filled indentations. A filled indentation would reflect the acoustic energy at a higher point corresponding to the surface of the fill material.

Filled Indentations

Figures 3 and 5 are images of four different filled indentations. These can be separated into two types. In the first group (Figure 3), the centers of the indentations are obscured by dark spots. Changing the lift-off did not affect
Figure 2. Two different acoustic microscope images of empty Vickers indentations in float glass. 

the image suggesting that the dark contrast is due to surface orientation. Close examination reveals the presence of interference fringes within the spots confirming that the surface is not flat. The images indicate that one application of glass was placed in the indentation and hardened without smoothing (see Figure 4). The surface of the fill material is sharply tilted such that most of the reflected energy is scattered and does not return to the lens resulting in a dark image. The energy which does return interferes with itself producing the interference fringes. Outside of the fill material in both images are bright reflections from the original indentation surface. This also suggests an abrupt edge to the fill material indicative of a lump of material without a smooth transition to the indentation surface. 

Figure 5 shows images of the other two filled indentations. These are quite different than the previous images in Figure 3 and, at first glance, bear closer resemblance to the empty indentation images. There are differences
Figure 4. A sketch of the Vickers indentation and glass fill material corresponding to acoustic micrographs in Figure 3.

however. In Figure 5, there is similar contrast from the centers to the edges and the details of the indentations are easy to see throughout. There are no large bright or dark areas corresponding to regions in or out of the focal plane of the lens unlike the empty indentations images which were dark in the center and bright at the edges. Careful observations of the B-scans of the indentations shown in Figure 5 indicated that the surfaces within the indentations were just below that of the surrounding material and there were no other strongly reflecting surfaces deeper. There are also no fringes or other contrast differences due to topology. This indicates that these indentations were filled uniformly and that the surface is quite smooth. Close examination of the images show slight distortions which may indicate the presence of different layers of material as shown in Figure 6. The images here suggest that the indentations were filled with a series of thin layers of glass which bond smoothly to the surface. The quality of this method is quite apparent from the images. While the indentation remains visible, but there are no obvious flaws between the original glass and the repair material.

CONCLUSION

Filled Vickers indentations in float glass can be differentiated from empty ones using an acoustic microscope by utilizing the effect of defocus on the acoustic micrographs. In the case of the empty indentations, it is possible to defocus the instrument such that all surfaces of the indentation pass
through the focal plane and therefore produce a strong reflection. The filled indentations produced two different types of acoustic microscope images. In one case, a single "lump" of glass placed in the indentation obscured the center. In the other case, the center was visible but could not be focused to a bright image since the indentation was filled with what appeared to be a number of thin, smooth layers. The surface of these indentations, from observation of the B-scans, was just below that of the surrounding material. The details of the indentation images in this group were clear, indicating that good bonding existed between the fill and original glass without voids or other flaws. The differences between the two methods of repair was obvious from observation of the acoustic micrographs.

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REFERENCES
