Laser Cutting of Thin Gold Foils

Rudolf Meeß[1], Daniel Hagedorn[1], Frank Löffler[1]

[1]*Physikalisch-Technische Bundesanstalt, Germany*

Rudolf.Meess@ptb.de

Abstract

The AIDA detector (Advanced Impact Detector Assembly) is a device for the in-situ measurement of the kinetic energy of micrometer-sized particles in space. Structured gold foils of 50 µm in thickness are used here as absorber arrays, cut by laser ablation. A total detection area of about 33 cm^2 is divided into 256 squared elements, lateral length 3.6 mm, in a 16x16 array. The connecting ligaments are of approx. 20 µm in width. During processing, the pulsed UV laser and the custom built positioning system are synchronized by the encoder signal of the high precision stages to provide for geometrical accuracy. A challenge is the fixture and handling of the gold foils to avoid mechanical and thermal deformation of the very sensitive structures and to minimize adhering debris. A novel procedure is presented to solve these tasks by using capillary forces on the fixed surface and a protecting film on the free surface of the foil by means of a single fluid. The cutting process is controlled in-situ. As a result, the microstructured foil is clean, distortion low, and the foil can be fixed on a silicon-based thermopile array.

1 Introduction

In the scope of the AIDA project [1], the task was to develop a process to fabricate absorber sheets with high accuracy and deliver several test sheets made of copper and 10 final absorber sheets made of gold. A laser cutting process was chosen to manufacture the sheets. Procedures for laser cutting of thin foils are well known. Ultra short pulses are preferred due to less thermal distortion. But thermal distortion and the contamination of the surface due to debris can even be minimized when processing with UV-laser pulses in the ns-range. Mechanical distortion during fixation and handling of the sensitive structures must be minimized in all cases. Furthermore, the high reflectivity of a fresh copper and gold surface can lead to problems during laser processing. Finally, the process also has to be controlled in-line to avoid scrap.

2 Experimental

Opaque gold foils with a thickness of 50 µm (+/- 10 %) are used for the final absorbers which are reported here (supplier “Goodfellow GmbH, Germany”). Each foil is attached to a new glass mask, a quartz-glass carrier with high flatness.

To match the demands, an image reversal photoresist is used with a kinematic viscosity of 24 cSt at 25 °C and a spectral sensitivity for wavelengths between 310 nm and 420 nm. The solvent is methoxy-propyl acetate. The photoresist is wiped carefully onto both sides of the foil by means of a soft and clean fabric. The metal foils can be aligned precisely on the glass substrate without damage by means of the wet fluid film. They are fixed to the substrate by a mild drying procedure. The film boundaries here act as diffusion barriers. In addition, on the free surface, the dried photoresist may act as an absorbing sacrifice layer at the beginning of laser processing as it reduces the amount of reflected light.

High precision positioning and laser cutting repeatability is guaranteed by a dedicated 4-axis robotics with a spatial resolution of 0.1 µm, which was also used e. g. for the photolithographic fabrication of strain gauge structures on metallic cylinders [2, 3]. Precise positioning is assisted by a camera system with a resolution of 1.5 µm/pixel. The lines of the orthogonal grid are cut sequentially. A 20 ns pulsed 355 nm UV laser is used for that purpose. The spotsize is approx. 10 µm, the average output power is 4.5 W at 25 kHz. Laser cutting of each line is repeated 13 times until the cut through is completed. Each pulse is triggered by the encoder of the corresponding axis with a pitch of 5 µm. The cutting process is verified in line by light transmission of the laser beam through the gap of the metal foil, when completed.

After cutting, the absorber sheet is detached using an acetone bath. The solvent removes the dried barriers at the boundaries of the still fluid film - the sheet floats. It can then be moved from the glass carrier without the lower surface being damaged due to the built-up fluid film thickness. The structured foils are cleaned subsequently in a second acetone bath and finally in a third bath with isopropanol alcohol to avoid residues on the surface. The absorber sheets are then dried and returned to the transportation case in which they were delivered.

3 Results

Figure 1 shows a micro photograph of an absorber sheet before and figure 2 shows it after the cleaning process. The positive effect of the surface protection film on the removability of debris can be seen. The dark areas disappear with the removal of the film by means of the solvents.

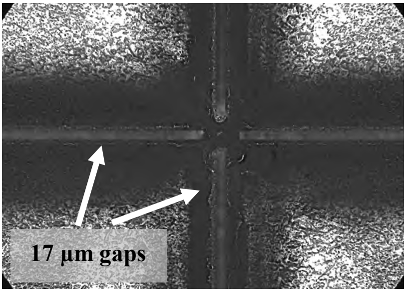

Figure 1: Micro photograph of Au absorber after laser processing (mag. 100 X)

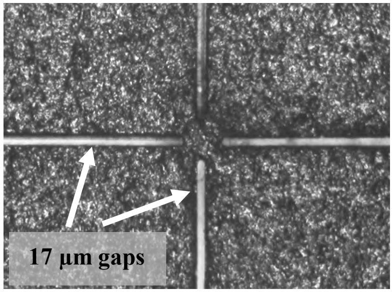

Figure 2: Micro photograph of cleaned Au absorber (mag. 100 X)

Figure 3 shows the SEM micrograph of a cut. The molten gold builds up a structure onto the photoresist film, which results in a free standing gold structure after the removal of the photoresist. The effect of the flow of the exhaust system can be seen in figure 4.

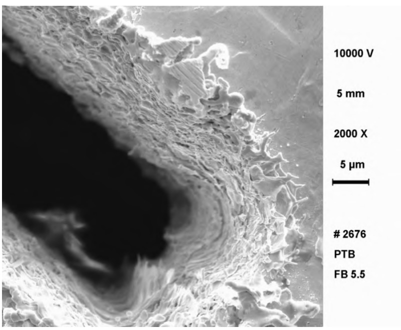

Figure 3: SEM micrograph of free surface and cut

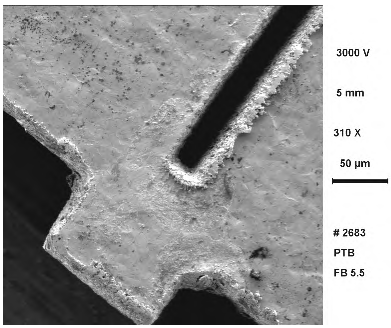

Figure 4: SEM micrograph of corner structure

A boundary joining element is shown here. The air flow direction goes from the left to the right in the picture. Optimizing the exhaust system should result in a minimized parasitic built-up structure. Nevertheless, the magnitude of these structures is considered to be non-destructive for the experiment or for the further processing of the sheets.

4 Conclusions and Outlook

A new procedure for the laser cutting of thin metal foils was developed which incorporates several advantages. Above all, a fluid film between the workpiece and the carrier leads to a strong adhesion of the workpiece on a planar substrate so that an exact alignment in heigth is guaranteed. The wet film allows the easy handling of the sensitive foil and conducts heat near the laser spot during processing. Secondly, the dried boundary of a film represents a diffusion barrier. This leads to a durable fixation of the sheets due to capillary forces before processing without loosing the fluid film between the workpiece and the carrier with its enhanced heat transfer. During laser processing the locally dried fluid prevents the metal sheet from disrupting the capillary effect and simultaneously protects the free surface against debris from the laser processing. Finally, the processed sheets can be detached and cleaned easily by means of an appropriate solvent and procedure. In a next step, the exhaust system will be optimized to reduce the built-up structures at the walls of a cut.

References:

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