Wafer Inspection Based on Photothermal Effects

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1. Introduction

Currently the majority of wafer inspection tools use either photons (e.g., laser), or charged particles (e.g., electron beam) as the interrogation agents. Based on the illumination and collection scheme, the optical tools can further be classified into bright-field (image forming) or dark-field (light scattering) tools. In principle, a bright-field (BF) tool illuminates the object through the objective aperture, and collects both the scattered and reflected light through the same aperture to obtain an image. On the other hand, a dark-field (DF) tool only collects the scattered light from the object. DF tools have the throughput advantage because they can detect defects much smaller than the spot size. However they are not very effective in detecting certain types of defects such as planar defects.

Wafer inspection using electron beam (e-beam) has several advantages over optical tools. The e-beam tool provides much higher resolution (as high as 1 to 5nm) due to its nanometer spot size. In Furthermore, it can detect electrical defects because of the nature of e-beam. This unique “voltage contrast” mode enables the e-beam tool to be quite effective in performing High Aspect Ratio[1] Inspection (HARI), which is impossible to accomplish with the current optical tools. The major drawback of the e-beam tool is its throughput: several hundred times slower than an optical DF tool.

Since HARI will account for about 25% of all wafer inspection in the near future, it is critical to derive a new inspection technology that has the ability to detect such defects with a throughput that is production worthy. Recently a new optical inspection tool based on Direct-to-Digital-Holography (DDH) technology, which uses both intensity and phase of light to detect defects, is claimed to have greater detection sensitivity as well as the ability to detect high aspect ratio defects. The throughput of the DDH tool is on par with a typical optical BF tool.

We propose an optical inspection technology based on photothermal effects. In this approach, both static (DC) and dynamic (AC) light scattering information is collected and processed. Such information would provide us the opportunity to detect high aspect ratio defects.

[1] Height to width ratio greater than 4:1, a result of shrinking the width of a feature such as via, contact hole, or trench.

2. Photothermal Effect

When matter is exposed to light, optical energy is absorbed and eventually converted into thermal energy. According to the 2nd law of thermodynamics, this thermal energy (heat) is

3. Description of Methodology

The second approach involves the use of two laser beams with different wavelengths, as illustrated in Figure 1. In this setup, a pump laser (e.g., 266nm) is used to excite the sample area to be inspected, and a probe laser (532nm) is used to detect the changes in the scattering field due to localized temperature rise on the sample that is related to the absorption as well as the reflectivity of materials.

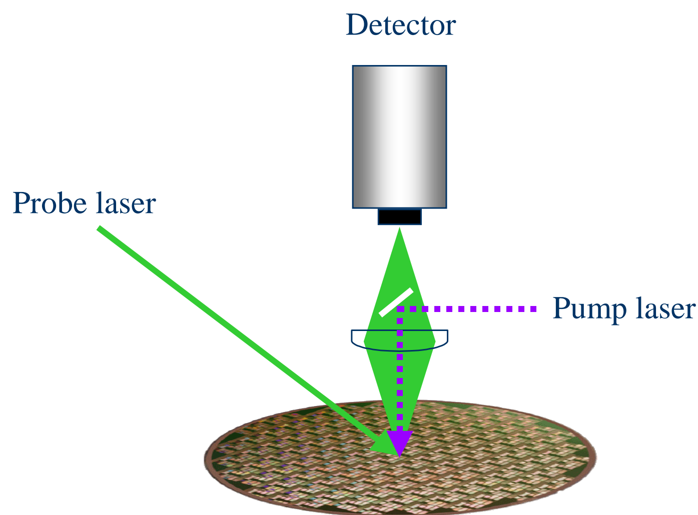

Figure 1. Proposed POC system 2 – Dual-beam optical inspection.

The pump laser used in this technique is typically a pulsed or chopped laser with a fixed repetition rate. This periodic bombardment from the pump laser will create a thermal lensing effect on the sample due to the absorption of photon energy on the sample. Different materials have different optical, thermal and mechanical properties and therefore the strength of this thermal lens will be different if a defect is present on or beneath the sample surface.

This periodic change also has an effect on the interaction of the sample and the probe laser. The effect includes the change of both the reflected and scattered light from the probe laser. That is, the collected light from the probe laser will be modulated by this effect, which can be used to:

- Perform die-to-die inspection with the aid of this modulation signal, in addition to the regular scattered light.

- Perform Real-Time Classification (RTC) with this modulated signal because it contains the phase information that is related to material properties.
- Detect subsurface and high aspect ratio defects because the 3-D thermal gradient of the irradiated area is embedded in the signal.

Figure 2 shows the different scattered light signals between the conventional scattering, which is more like a DC signal, and the modulated scattering, which is the convolution of both the DC and the AC signal. This modulation data can be obtained by using a phase lock loop (lock-in amplifier). Synchronous averaging can be performed on multiple data segments to eliminate random noise. Fourier transform can be performed on the averaged data to reveal harmonics in the signal that are useful for defect classification.

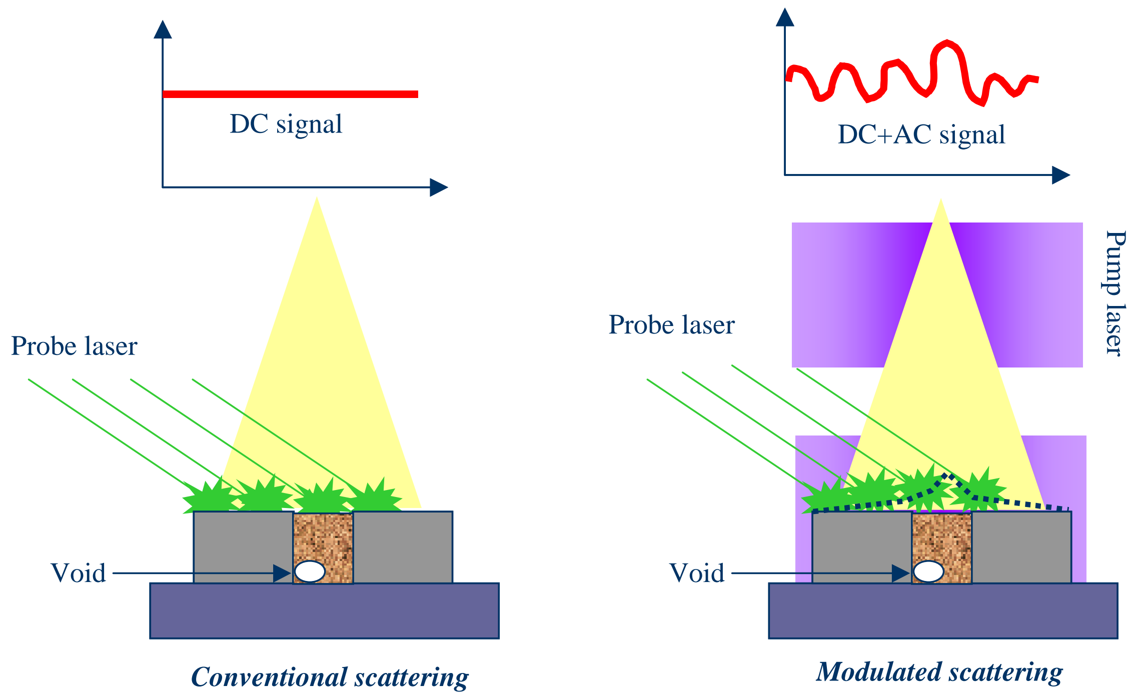

Figure 2. Conventional vs. Modulated scattered light.