Deposition of Al and Cu nanoparticles on Silicon Wafer using a Picosecond Nd:YAG Laser: An Experiment-based Parameter Optimization Guide

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Abstract: The optimization of parameters for laser deposition of nanoparticles on Si-wafer is studied. The threshold of laser energy, pulses per laser shot and overlapping is crucial in order to achieve the best deposition results.

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1. Introduction

Sputtering or printing of nanoparticles can be described as the transfer of atoms from a donor surface to the surface of a substrate using a laser source. In this research, the optimization process of laser sputtering on Si-wafer is presented. Al and Cu particles are removed from one-side coated glass and they are deposited on Si-wafer substrate. In order to grow Al and Cu particles on substrate, E-less nickel is plated and afterwards gold covered for further shear testing [1]. Different repetition rates produce a different average output power by a picosecond laser. Based on this, the pulse energy and intensity of each sputtering line is calculated. The FIB cross section of particles on the substrate shows the wettability and smooth surface which could be used in electronic pad production in each shape and diameters [2, 3].

2. State of the art

Sputtering can be observed when the direction of movement of an atom is focused at a target with an energy that is sufficient to form bonds with other atoms [4-6]. The silicon wafer is passivized by Si3N4 to have a composite barrier laminates and to decrease the permeation of particles in substrate [7]. The procedure type which has been used in this paper is to deposition nano metal particle by direct laser radiation from one side coated glass as a donor [8-9].

3. Step-By-Step optimization process

In the optimization process three parameters are subject to modification, namely repetition rate, number of pulses per position and laser pulse overlapping. Upon sputtering the lines, E-less nickel plating and subsequently gold-plating ensured passivation in order to have growth and coalescence of the deposited particles [10-12]. The laser beam diameter in focus is around 60 µm using a 163mm Theta-Ronar lens. Figure 1 shows the Al and Cu printed nanoparticles on Si-wafer substrate. Upper row with red color is representative of repetition rates and the second row is average output power. Two downer rows are illustrative of laser pulse intensity (blue) and laser energy (green) respectively. The highest energy which produces a homogenous deposition of particles is at 87 µJ with 230 KW/cm² intensity.

![Fig.1 Optimization of Repetition rates and Pulse energy Aluminum (a) and Copper (b)](image-url)

In the next step pulses per laser shot were changed from 1 to 40 for deposition of Al on substrate. For less than 8 pulses per hole the particles are not sputtered well on the substrate in which case the samples later fail the adhesion...
tape test. For 8 to 9 pulses a good deposition can be observed. Finally the distances between shots is optimized from 1-40µm. It can be concluded that 80% overlapping guarantees the production of perfect lines.

4. Analysis

The next metal to be plated on top of the sputtered layer is Ni, and ultimately Au. Figure 2a shows an exemplary cross section of Al deposited on silicon wafer substrate after E-less nickel plating with 4µm growth height and 500 nm gold plated for coalescence of particles for later bumping and shear tests. After plating, only a very small number of micro voids can be found. The average roughness of ten peak-to-valley height for Al is 1.5-2µm. A slightly higher roughness between 2–3µm was found for the deposition of Cu particles, which can be well seen in the zoomed out image 2b.

5. Conclusion

Multi-layer thin films has a crucial role in microelectronic applications, MEMS and nano electromechanical systems. In this study it is presented how parameters for laser sputtering of nanoparticles can be optimized. The threshold of repetition rate and afterwards pulse energy is measured for sputtering the Al and afterwards Cu onto the Si-wafer substrate. The pulse overlapping and number of laser pulses per each shot are also optimized. Distance of 10-11µm produces perfect lines with smooth edges. Optimal sputtering was achieved for a repetition rate above 80 KHz (6.61W of Average Power, Energy of 82.6µJ). By increasing the number of pulses to more than 15, the high energy leads to an impaired layer on the substrate. The sputtering of nanoparticles is demonstrated by the preparation of an Under Bump Metallization (UBM); although, the laser sputtering technique may be used for a multitude of other applications like: bonding technology for microelectronics, as well as micromechanical and micro-optical devices and components.

6. References

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