Available online at www.sciencedirect.com

ScienceDirect

Procedia Chemistry 1 (2009) 792–795

Procedia Chemistry

www.elsevier.com/locate/procedia

Proceedings of the Eurosensors XXIII conference

A robust, fine pitch probe card

M. Rosamond*, A.J. Gallant, D. Wood

School of Engineering, University of Durham, Durham, DH1 3LE, UK

Abstract

A new type of probe card is described which consists of inclined nickel cantilevers formed on top of a three dimensional PDMS layer. A prototype card has been built with an in-line pitch of 23 µm. The presence of a PDMS layer beneath the cantilevers creates mechanically robust probes. The probes can apply up to 100 mN contact force and be deflected up to 40 µm without damage. Typical contact resistances of less than 5 Ω against gold and 15 Ω against copper are reported. The leakage current between adjacent probes is less than 1 nA measured at 100 V.

Keywords: Probe card; PDMS; Greyscale lithography; Fine pitch; Robust

---

1. Introduction

Wafer level testing is the process of evaluating the functionality of ICs before the wafer is diced and individual ICs are packaged. To perform such testing, probes are used to provide a temporary electrical interface between terminals on the wafer's surface and test equipment. Probing technologies range from simple needle/epoxy to complex micro-machined designs consisting of 10,000 probes capable of addressing 263 devices in a single touchdown[1]. Micromachining is gaining favour over traditional fabrication methods since the cost and time taken to produce high pin count probe cards is significantly reduced. Additionally, the use of UV lithography allows geometric control at the micron level which is required for manufacturing probes suitable for addressing fine pitch bond pads.

A disadvantage of micromachining is that the standard suspended beam structures are easily damaged during handling or use. Also, as the dimensions of the probes are reduced, the structures become too weak to provide the contact force required to form a reliable low resistance contact. In this paper a probe design is described which has no suspended parts and was found to be mechanical robust during handling and testing. This contrasted with our earlier suspended designs[2] which were found to be mechanically fragile.

The design described here used a shaped PDMS layer to provide the required mechanical compliance whilst nickel cantilevers provided conductive tracks and nickel probe tips the electrical-mechanical interface. Since

---

* Corresponding author. Tel.:+44-191-334-2514; fax: +44-191-334-2407.
E-mail address: m.c.rosamond@durham.ac.uk.

doi:10.1016/j.proche.2009.07.197

mechanical compression of the PDMS layer provided the contact force it was possible to reduce the geometry of the probes without imposing a corresponding reduction in stiffness. This allowed the fabrication of a fine pitch mechanically robust probe card.

2. Fabrication

The probe design consisted of inclined nickel cantilevers formed on top of a wedge shaped PDMS layer. To form the PDMS layer, uncured elastomer was moulded onto a glass substrate. The mould was created by as follows: First a 55 µm thick layer of AZ9260 photo resist was coated onto a silicon wafer and exposed using a binary halftone mask in proximity contact. The halftone pattern of the mask spatially modulated the exposure dose such that when the resist was developed it formed the desired wedge shape. Next the resist was sputter coated with a 30 nm titanium adhesion layer and 100 nm copper seed layer. Low stress copper was then electroplated to a thickness of approximately 500 µm. The rough surface of the copper was polished flat such that it was parallel with the silicon substrate beneath before the silicon wafer, resist and titanium were dissolved in 90 °C 350 g/l KOH. The surface of the copper mould was then sputter coated with 100 nm of gold to aid de-moulding of the PDMS.

The process flow for the prototype probe card is shown in Fig 1.

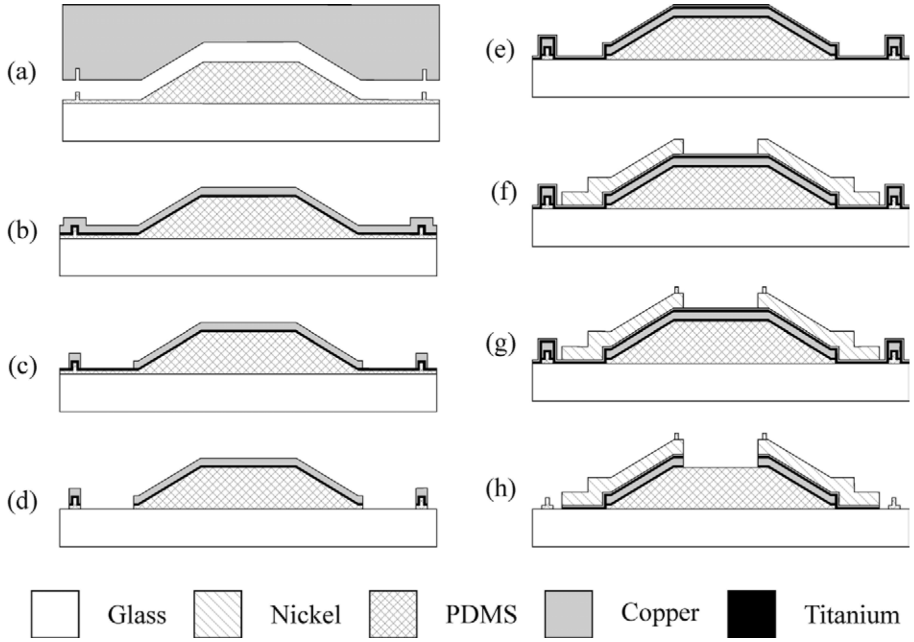

Fig 1.Fabrication process flow

A small volume of uncured PDMS elastomer (Sylgard 184 Dow Corning mixed 10 parts elastomer to 1 part curing agent) was dispensed onto the gold coated surface of the copper mould. A glass wafer was placed on top of the mould and the pair placed into a mechanical vice. The assembly was then placed in a desiccator to remove trapped air before being transferred to a 140 °C hotplate where it was baked for 30 minutes. After cooling the wafer and mould were removed from the vice and a scalpel blade was inserted between the glass substrate and mould causing the mould to delaminate from the PDMS layer (Fig 1(a)). The PDMS was then washed in acetone before being exposed to oxygen plasma. This treatment was performed to ensure the adhesion between the PDMS surface and subsequent sputtered metals.

A 30 nm titanium adhesion layer and 60 nm copper seed layer were then sputter coated before electroplating copper to a thickness of 5 µm (Fig 1(b)). Resist was then spun and patterned to define anchor regions for the nickel cantilevers. The copper was wet etched then the resist was stripped (Fig 1(c)) and the titanium and PDMS dry etched

(Fig 1(d)). It was necessary to perform these etching steps to remove a thin covering of PDMS which was present across the substrate surface and resulted from the moulding process.

A second 30 nm titanium and 60 nm copper layer were then sputter coated (Fig 1(e)) before thick layers of AZ920 photo resist were spun and patterned to define the cantilevers. Nickel was then deposited to a thickness of 15 µm from a sulphamate solution to form the cantilevers (Fig 1(f)). The process was then repeated to form probe tips on the end of each cantilever (Fig 1(g)). Finally the cantilevers were electrically isolated by a timed etch of the expose copper and titanium layers.

Images of the completed probe structures can be seen in Fig 2.

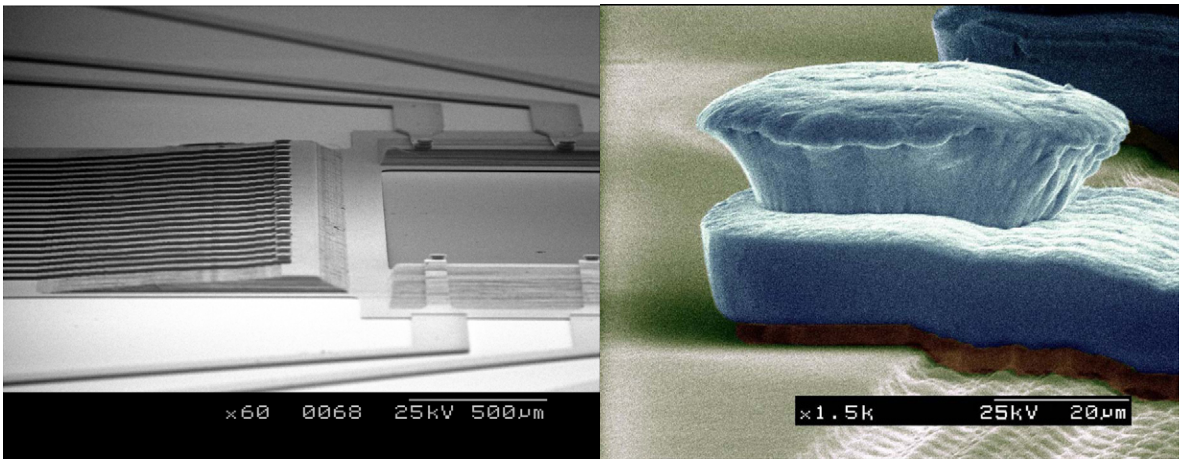

Fig 2 (a) Probe array; (b) Individual probe tip

Using this fabrication process, arrays of probes with an in-line pitch as small as 23 µm and tip co-planarity of less than ± 1.5 µm were produced. However due to their extremely high density the testing of such devices was not possible. Instead, mechanical and electrical characterization was performed on arrays of cantilevers at 200 µm pitch. These are the devices shown in Fig 2.

3. Evaluation

Force-deflection behavior of an individual cantilever was measured using a bespoke system. The system used a tungsten needle which was brought into controlled contact with the tip of an individual cantilever, causing it to deflect. An LVDT was used to determine the position of the needle whilst a balance was used to measure the contact force. Adjustments to the displacement data were made to eliminate the affect of deflection within the balance during the testing. The force-deflection behavior of 1 mm long, 50 µm wide and 15 µm thick probes is shown in Fig 3(a). As can be seen the force increased in an exponential manner with deflection reaching a value of approximately 100 mN at a probe deflection of 35 µm.

An analytical model was used to predict the stiffness of a nickel cantilever of the same dimension but without the PDMS layer. It showed that at 35 µm deflection a contact force of only 0.21 mN was expected. Therefore it was concluded the stiffness of the probe structure was almost entirely determined by the deformation of the PDMS layer. After deflecting the probes 40 µm (40% of the PDMS thickness) there was no evidence of damage to either the nickel or underlying PDMS.

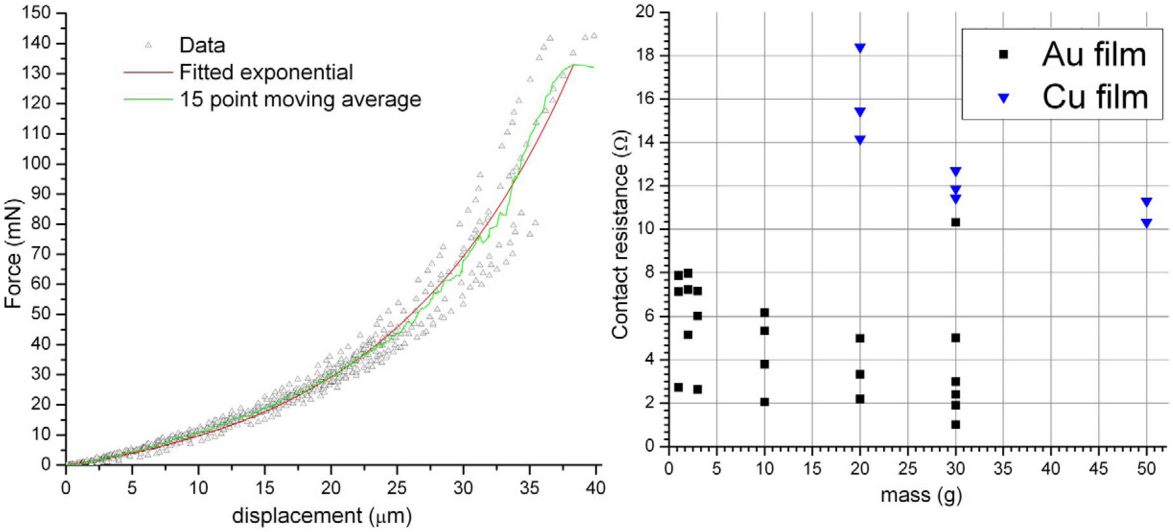

Fig 3 (a) Force-deflection behavior; (b) Contact resistance as a function of film material and applied mass

To perform contact resistance measurements, substrates coated with metal films were placed on top of the probe array and a mass placed on top. The resistance between two adjacent probes was then measured before the path resistances were subtracted and the value halved to obtain the resistance associated with an individual contact. The results of this testing can be seen in Fig 3(b).

The probe array consisting of 48 probes in a perimeter layout and therefore the contact force per probe could be assumed to be $^{1}/_{48}$ that of the applied weight. However, it was not known if the weight was distributed evenly across all the probes and therefore the exact value of the contact force on the probes being measured could not be known.

It can be seen from Fig 3(b) that the contact resistance decreased with increasing mass and the resistance to gold was lower than it was to copper. This is due of the presence of native oxides on the copper surface and greater hardness of copper compared to gold. The contact resistance to gold was typically lower than 5 Ω for a mass of 30 g whist the resistance to copper was less than 15 Ω. These resistances are higher than is typically required[3] (less than 1 Ω) however their value could be reduced further by increasing the contact force.

The leakage current between two adjacent probes was also measured. A leakage of less than 1 nA was measured over a voltage sweep of -100 to +100 V.

4. Conclusions

A probe has been described consisting of nickel cantilevers formed on top of a wedge shaped PDMS layer. The fabrication used a lithographically defined copper mould to shape the PDMS layer on to glass and through resist electroplating to form the nickel structures. Force-deflection behavior was measured using a bespoke system and the contact force was found to increase exponentially with deflection. No damage to the probe was observed during handling or after multiple deflections of up to 40 μm. The contact resistance to copper and gold films was measured. Although these were a little high they were stable and could be reduced by further increasing the contact force.

References

[1] Mann W R, Taber F L, Seitzer P W, Broz J J. The leading edge of production wafer probe test technology, IEEE ITC 2004; 1168-93
[2] Rosamond M, Wood D. Substrate independent fabrication of a non-planar probe card, Microelectronic Engineering 2007; **84**:1207-10
[3] Aitken R, et al. International Technology Roadmap for Semiconductores: Test and Test Equipment 2007