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Scalable Platform for Batch Fabrication of Micro/Nano Devices on Engineering Substrates of Arbitrary Shapes and Sizes

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Abstract

Silicon wafers with standard sizes and shapes have served as the batch fabrication platform for microfabrication of micro/nano devices for decades. However, there is a strong demand to batch fabricate micro/nano devices on other engineering materials (e.g. titanium, stainless steel, diamond, and ceramics) of complicate shapes and sizes designed for important applications. Unfortunately it is extremely difficult to meet the demand due to various challenges involved during microfabrication. Here we present a novel batch fabrication platform which can be used to facilitate the batch fabrication of thin film devices on substrates with arbitrary shapes and sizes. This platform will eliminate photolithography related defects such as edge bead formation, which will enable fabrication of thin film devices at the edges/corners of arbitrary shaped and sized substrates. At the same time it will enable uniform and bulk polishing of these substrates. As a proof of concept, parallel/batch fabrication process was successfully applied and proved by fabricating thin film piezoelectric force sensors on polygonal shaped stainless steel plates.

Keywords: Batch fabrication, Microfabrication, Thin film sensors

1 Introduction

In numerous engineering processes, such as manufacturing, the ability to measure temperatures, stresses, cutting forces, etc. is not only crucial for monitoring the machine tools but also for reliable real-time process control (Zheng, 1993, Totis, 2011, Ma, 2011, Siddhpura, 2013). Micro/nano sensors and devices present a promising way to advance process monitoring and control. However, in the industrial processes, such as manufacturing, there are

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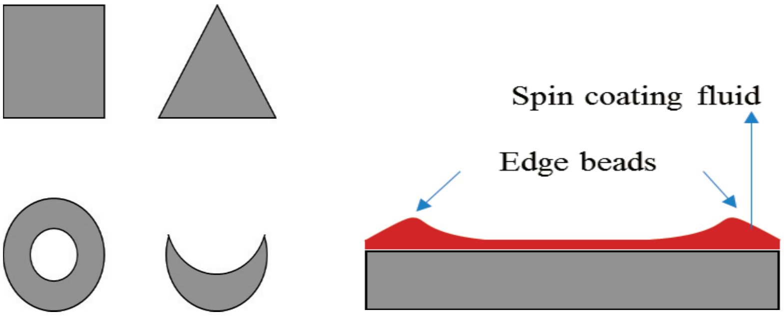
tremendous challenges for the adaption of micro/nano sensor and devices, such as substrate's geometric constraints, material compatibility, and harsh operation conditions (Siddhpura, 2013). Recent years have seen a rigorous development of such sensing techniques, where micro/nano sensors are fabricated on engineering materials, such as PCBN cutting tools, sapphire, and stainless steel etc. (Datta, 2006, Li., 2013, Werschmoeller, 2009, Zhang, 2006, Choi, 2007). There is a strong demand to batch fabricate micro/nano devices on other engineering materials (e.g. titanium, stainless steel, diamond, and ceramics). Unfortunately it is extremely difficult to meet the demand of batch fabrication due to the substrates needed for engineering applications normally are in complicate shapes and sizes. Unlike conventional silicon wafer based platform for batch fabrication, wafers of other engineering materials with satisfactory surface quality are extremely difficult to obtain, sometimes impossible due to manufacturing limitations. Moreover, techniques involving fabricating devices on large wafers of metals and ceramics, and later use laser or diamond saw dicing to obtain devices of suitable sizes and shapes would create problems due to the harsh conditions in these processes, which easily induce cracks and residual stresses. Some more challenges are discussed below.

1.1 Bulk Surface Polishing And Fabrication

The substrates such as PCBN, sapphire, stainless steel and other potential substrates have to undergo surface polishing process before thin film devices can be fabricated on them. Individual polishing and fabrication of these devices is a very time consuming process. These issues become more time consuming and cost ineffective when large scale production of such devices are in demand. In order to achieve high throughput, an efficient batch fabrication process is needed. The approach of parallelized or batch fabrication in microelectronics often leads to high yield, cost reduction and improved miniaturization. In order to keep pace with competition, the industries have to achieve short production time and high throughput under lowest investment (Tu, 2011).

1.2 Geometry Affected Photolithography Challenges: Edge Bead Effects

In addition to the need of batch fabrication of these miniaturized devices, there is another challenge of overcoming geometric constraints i.e. to fabricate the sensing devices at the edge / perimeter of the small substrates for better sensing spatial and temporal resolution (Li, 2013, Werschmoeller, 2009). During the photolithography process, the spin coating of photoresist and other such polymers/chemicals often results in planarization defects such as edge bead formation (Carlson, 2007, Chaplick, 2010, Elliott, 2012, Ishida, 1996, Jekauc, 2004, Lee, 2011, Oberlander, 2001, Rekhson, 1991) on the substrates as shown in Figure 1. The edge bead formation depends on various factors



(a) (b)

Figure 1: AlN force sensor consisting of top and bottom electrodes sandwiching a piezoelectric AlN thin film disc.