High Throughput SPM for Nanopatterning and Nanometrology

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Abstract

Extreme Ultraviolet Lithography (EUVL) will becoming the driving force for high volume manufacturing of nanodevices below 5 nm. However, other complementary techniques with very high resolution of patterning are required to meet current and future patterning challenges.

The future patterning challenges includes: 1) High patterning resolution, below 10 nm; 2) capability of patterning in 3D; 3) sufficient wafer-scale throughput; 4) the capability of closed loop metrology and 5) the capability of measuring through layers for alignment and overlay applications.

Scanning probe microscopy (SPM) has shown a great degree of nano-scale control, which led to the development of a wide variety of scanning-probe-based patterning and metrology methods [1]. Some of the patterning capabilities in terms of resolution and metrology are unmatched by other lithographic techniques. However, the limited throughput of scanning probe lithography and metrology has prevented its exploitation for technological applications.

In this talk, we will present an overview of variety of scanning probe nanopatterning techniques with their Pros and Cons. Next, we will present the development of a high throughput scanning probe instrument (HT-SPM) which consists of several miniaturized SPM operating in parallel to meet the aforementioned requirements [2]. The ability to control the tip-sample force at sub-nanometer scale allows robust 3D nanopatterning. This is demonstrated by the patterning of nanocontact holes in various sizes (down to 10 nm) and pitches. Since these techniques will be used complementary to other existing nanopatterning techniques, i.e. optical nanolithography techniques in a hybrid configuration, it is important to be able to perform alignment metrology prior to patterning and overlay metrology while patterning. To meet the required accuracy, the overlay and alignment must be performed on the product features. Moreover, the presence of a metal resist and other opaque layers, which are optically non-transparent, makes the alignment and overlay very challenging. We have recently developed a technique called SubSurface Ultrasonic Resonance Force Microscopy (SSURFM) that can measure buried patterns though opaque layers with sub-10 nm resolution [3].

Experimental results include the proof-of-principle of using SSURFM to locate existing buried nanopatterns (lines of 50 nm) and subsequently using our patterning technology to manufacture nanocontact holes aligned to the existing buried lines. This example demonstrates the usefulness of the suite of technologies developed at TNO consisting of the high throughput parallel scanning probe patterning and the subsurface nanoimaging capabilities for alignment and overlay, especially through opaque layers.

Reference

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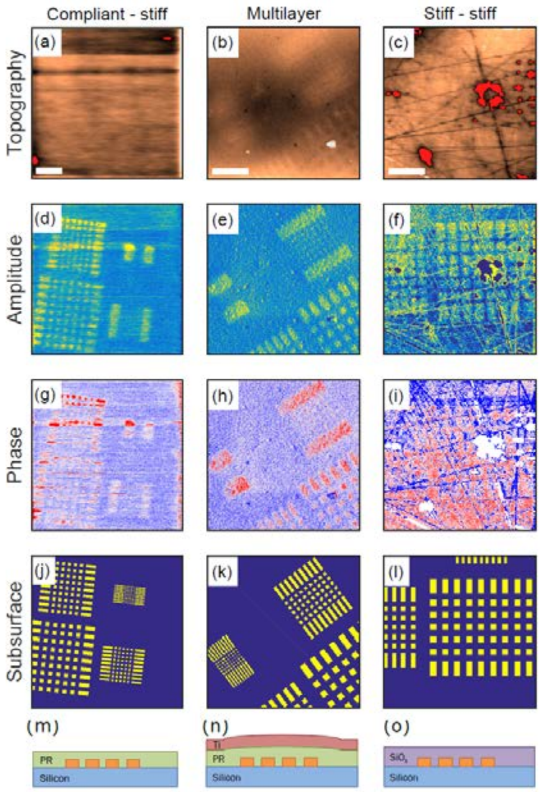

Figure 1: Surface and subsurface probe microscopy of several samples. The surface topography does not reveal any information about the buried features and the subsurface probe microscopy resolves the buried features. This concept is being developed for wafer alignment and overlay on product features (patent pending).

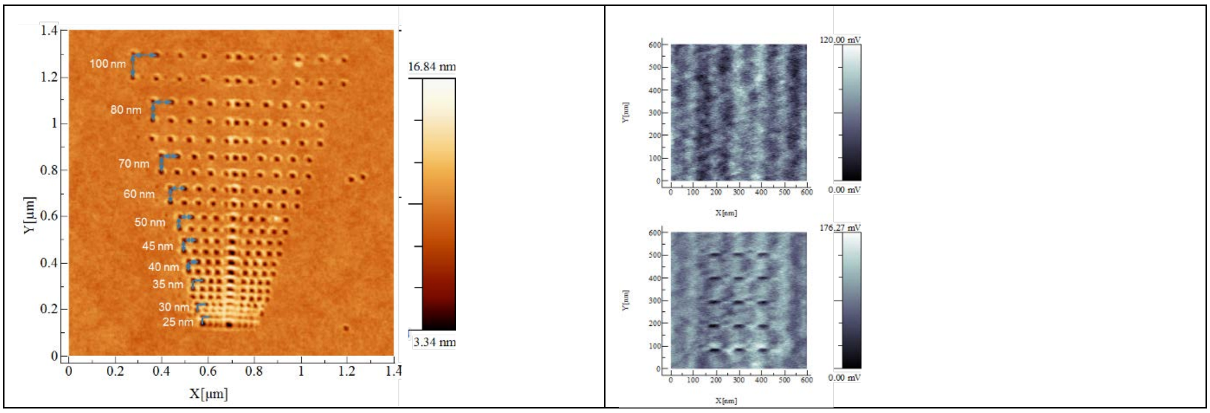

Figure 2:Left: nanopatterning of contact holes on a metal resist with various pitches. Right top: subsurface image of buried lines. Right bottom: nanopatterned contact holes, aligned by subsurface probe microscopy on top of the buried lines and fabricated with the SPM tip.