Mitigation of EUV Mask Blank Substrate Pit and Scratch Defects by Accelerated Neutral Atom Beam (ANAB) Processing

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ABSTRACT

EUV mask blank substrates will be subject to extraordinarily demanding requirements upon flatness, smoothness and absence of residual defects. To date, no combination of available surface preparation techniques has been able to produce essentially perfect substrates with zero residual defect populations. A critical problem yet to be resolved involves small numbers of nanoscale divots and scratches which are generated by the operations used to meet smoothness requirements. A new non-contact surface sputtering technique known as accelerated neutral atom beam (ANAB) shows promise for mitigating the divot and scratch defects without increasing surface roughness and without altering flatness and planarity. This paper describes a mask blank substrate study which has been conducted to demonstrate the ANAB defect mitigation capability.

Key Words: EUV mask blank substrate, accelerated neutral atom beam, ANAB, lateral sputtering

1. INTRODUCTION

Ability to manufacture defect-free mask blanks must be established before EUV lithography can be implemented into production. Challenging problems exist in achieving mask blank substrates able to satisfy defined requirements including surface flatness and roughness while also being entirely free of residual scratches, bumps and embedded particles. No combination of available surface preparation techniques has been found capable of accomplishing all of the flatness, roughness and residual defect demands. Extensive development efforts employing combinations of surface preparation techniques have been conducted under the direction of SEMATECH and have resulted in mask blank substrates approaching the defined goals, but a fully complete and practical solution has to date not been demonstrated. Substrates which meet flatness and roughness requirements can be produced but they still invariably exhibit non-zero counts of shallow pits and scratches having dimensions sufficient to produce printable defects on completed masks.

Exogenesis Corporation has introduced a new surface modification technique known as Accelerated Neutral Atom Beam (ANAB) processing which shows promise for being able to remove from mask blank substrates the residual defects that other techniques have not been able to eliminate. ANAB is conducted under vacuum by a beam of electrically neutral argon gas atoms which have average energies of a few tens of electron volts. ANAB can remove material by sputtering under conditions which inherently cause nanoscale bumps, scratches and pits to be diminished as the removal action proceeds. When used to sputter material from an extremely smooth surface, ANAB can remove a precisely controllable and uniform thickness of material without resulting in any increase of roughness. In the case of a mask blank substrate already planarized and polished by CMP, without creating any additional surface roughness, ANAB is capable of removing a sufficient depth of material so as to eliminate all residual pits and scratches.

Exogenesis and SEMATECH have collaborated to conduct an initial demonstration of feasibility of using ANAB for defect correction on EUV mask blank substrates. A representative mask blank substrate was characterized by

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