Particle Adhesion to Photomask Substrates

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Semiconductor manufacturing technologies require strict control on the size and number of particulate contaminants that can be tolerated on wafers and photomasks. Most present cleaning protocols rely on a fluid mechanical force or a combination of a fluid mechanical force and a chemical reaction (such as undercutting) to remove contaminant particles from surfaces. Dislodged particles may then be stabilized away from a surface of interest using electrostatic interactions. For future photomask substrates, many of the mechanisms that are effective in current mask cleaning will not be acceptable. Specifically, any etch-based process will not be tolerated, as substrate layers are too thin and roughness limits are too strict to accept the consequences of etching. At the same time, the critical particle size will drop, and fluid-mechanical based cleans will be increasingly ineffective at imparting the required removal force on the particles due to boundary layer effects. The development of viable cleaning techniques for the I.C. industry requires detailed understanding of the forces of adhesion between particles and substrates. In this work, experimental and modeling studies of the adhesion between photomask substrates and model contaminants with different characteristic length scales are presented. The model substrates include CrO_xN_y, TaO_xN_y, quartz, MoSi, and Ru. Model contaminants include micro-scale glass spheres and Si_3N_4 particles, as well as Si_3N_4 atomic force microscope (AFM) cantilevers with nanoscale radii of curvature. The predicted force distribution showed a very good agreement with the measured one for micron scale particles and for cantilevers with nanoscale pyramidal tip in both dry and aqueous environment.

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