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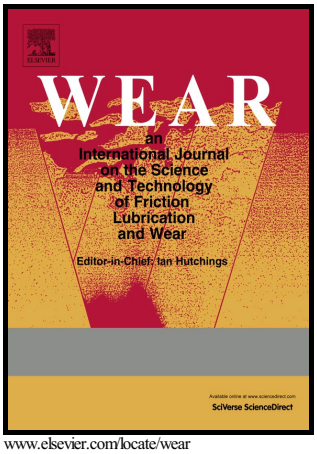

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Effect of wear of diamond wire on surface morphology, roughness and subsurface damage of silicon wafers

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Abstract

Wear of fixed abrasive diamond wire affects the quality of sliced silicon wafers, necessitating replacement of the costly wire. This paper analyzes the effect of wire wear on the surface morphology, roughness, and subsurface damage of as-cut single crystal silicon wafers. Scanning electron microscopy, confocal microscopy, and focused ion beam machining (FIB) are used to evaluate the surface morphology, areal surface roughness, and subsurface damage (cracks). Results show that, with increased wire wear, the wafers exhibit greater evidence of ductile removal, lower surface roughness, fewer but slightly deeper subsurface cracks, and lower average fracture strength.

Keywords: wear; diamond; wire sawing; silicon wafer; surface; subsurface; damage

1. Introduction

Silicon wafers for photovoltaic solar cells are manufactured by wire sawing processes, which slice mono-crystalline silicon ingots produced by the Czochralski (Cz) process or multi-crystalline silicon produced by the casting process. In recent years, there has been a shift from loose abrasive slurry wire sawing (LAS) to fixed abrasive diamond wire sawing (DWS), a trend that is forecast to grow [1]. While LAS involves cutting silicon by the abrasive action of loose silicon carbide (SiC) particles in a polyethylene glycol based slurry poured onto a stainless steel wire web, DWS uses diamond grits fixed to the steel wire with electroplated nickel or resin as the bonding agent, and a water based cutting fluid. DWS is advantageous over LAS as it provides increased material removal rate and lower silicon loss due to a smaller kerf. LAS involves three-body abrasion [2-4] of the wire, SiC grit, and silicon, leading to wear of the wire core. In comparison, DWS involves material removal by a two-body abrasion mechanism where the core metal wire is less likely to be worn. Other multi-wire sawing processes involve abrasive based electrochemical methods [5], and resinous diamond wire [6]. In a previous study, electroplated diamond wire manufactured by felt brushes showed better wear resistance [7]. The phenomenon of diamond wire break-in during initiation of cutting and its effect on process performance has been studied recently [8]. Related work on the prediction of diamond wire wear [9] and lifetime estimation has been also reported [10]. High stresses in cutting brittle materials by diamond wire has been shown to induce graphitization of the diamond abrasives [11]. Other studies of cutting single crystal silicon with diamond tools have shown tool wear to influence the