

# Temperature Effect on Antenna Protection Strategy for Plasma-Process Induced Charging Damage

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**Abstract**— In this paper, the leakage current of different drain-well diodes for plasma-charging protection has been simulated at high temperatures. The simulation shows that the high ambient temperature, especially during plasma deposition process, enormously enhances the efficacy of the protection diodes in protecting thin oxide. The efficacy of different diodes has been compared by simulation and experiment. Based on our discoveries, a strategic protection scheme for plasma-process induced damage (PPID) is proposed.

## 1. INTRODUCTION

Plasma processes are widely used in the manufacturing of VLSI devices for etching and deposition. However, it also induces charging damage to the devices. In 1989, Shone et al. proposed protection diodes as a means of avoiding wafer charging [1]. The diodes are connected in parallel to the gate providing an alternate leakage path for the plasma-induced current. Historically, junction breakdown voltage has had a lower value than gate oxide breakdown voltage and therefore, even reverse bias has been effective in protecting gates. As the thickness of the gate oxide is scaling down, the gate oxide breakdown voltage strongly decreases. It was predicted that for oxides thinner than 11nm, gated diode provides little or no protection [2]. However, later it was reported that the protection by diodes is still effective for 2.1nm– 3.2nm thin gate oxide FETs [3]. Even reverse diodes with high junction breakdown voltage can still offer some charging protection. This protection is due to their reverse bias leakage and can be adequate if they have a large enough area [4].

Apparently the protection diodes are more capable than what was anticipated. One of the explanations

of the enhancement of the efficacy of the protection diode is the presence of light during plasma processing. During the plasma process the diode reverse leakage current is enhanced by a photon generated current resulting from the light emission of the plasma [4].

However, the light effect is strongly affected by the metal on the top of the diode. If the diode is shielded from plasma illumination by metal, the reverse current of the diode rapidly decrease by more than one order of magnitude [5]. As the integration density of the VLSI technology continuously increases, the metal layers fabricated in the back-end processes increases from 3 layers to 5 layers, and even more. Furthermore, tiling of metal will block even more light, which makes it more likely that the protection diodes are shielded by the metal and there is no to plasma-assisted photo-conduction in these diodes.

In this paper, we report for the first time that the enhancement of the efficacy of diodes in protecting very thin gate oxides is primarily due to the high ambient temperature during the plasma processes. During the plasma etching the wafers can be heated to about 70°C and during the plasma depositions processes, the ambient temperature is even 400°C. Recently more and more research groups report the plasma damage is mainly due to the deposition process [6]–[8]. Therefore, studying the diode characteristics at high temperature becomes important for plasma damage protection prediction.

Since it is not possible in practice to measure the diode characteristics at 400 °C, a commercial simulator called SILVACO is used to investigate the diode behavior at elevated temperatures. The efficacy of different diodes is also compared under

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