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Comparison of POCl3 diffusion with phosphorus ion implantation for Czochralski and Quasi-mono silicon solar cells

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Abstract:
Both ion implanted and $POCl_3$ diffused emitters are used for industrial production of p-type Si solar cells. Formation of phosphorus doped emitter is known to perform gettering of impurities, however, gettering efficiency of these two diffusion techniques is not well quantified for single crystal Cz Si and Cast multi or Quasi-mono Si wafers. In addition, ion implantation can provide higher quality emitter with in situ oxide passivation[1]. This paper compares the performance of Quasi-mono and Cz Si cells fabricated with $POCl_3$ and ion-implanted emitters. Quasi-mono wafers have more defects and are expected to benefit from gettering. Large area screen printed p-type industrial cells with full Al-BSF cell structure were fabricated on commercial grade single crystal Cz Si and two different Cast Quasi-mono Si wafers with 50% and 80% mono-crystalline regions. Bulk lifetime was measured to evaluate the gettering efficiency of each technology before and after each emitter formation[2]. $POCl_3$ diffusion gave greater improvement in bulk lifetime of Quasi-mono wafers compared to ion implanted wafers, resulting in 0.7 ~ 1% higher absolute efficiency and over 5 ~ 15mV higher Voc compared to the implanted cells. However, in the case of Cz cells, bulk lifetime remained high and comparable for the two emitters. Therefore, Cz cells with implanted emitter gave 0.4% higher efficiency and 7mV higher Voc due to a higher quality emitter with in situ front oxide passivation.

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I. Introduction

Crystalline Si cells account for ~ 90% of the market share with ~ 55% cast Si cells and ~35% single crystal Cz cells [3]. Cast Si wafers are produced by conventional directional solidification process and by tailoring the growth conditions and seeding one can make either multi or Quasi-mono Si. Even though cast Si wafers have the advantage of lower cost, these wafers produce somewhat lower cell efficiency due to impurities, dislocations and grain boundaries. PV industry is trying to improve cast Si material by introducing single crystal seed and by tailoring the growth conditions which can lead to nearly mono or Quasi-mono materials [4]. Cast materials are known to benefit significantly from the traditional $POCl_3$ emitter formation due to gettering of defects and impurities which drives the impurities into the emitter region via a kickout mechanism [5]. However, it has been shown recently that the emerging ion-implanted emitter can lead to higher quality and more uniform emitter which also benefits from in situ oxide passivation during the implant annealing. This paper compares the $POCl_3$ diffused emitter and the ion-implanted emitter cells on Cz and Cast Si materials to assess the trade-off between gettering and quality of the two types of emitters.

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