Journal of ELECTRONIC MATERIALS, Vol. 42, No. 4, 2013
DOI: 10.1007/s11664-012-2467-x

Effects of the Physical Properties of Bismate Frits on Contact Formation Between Ag Electrodes and Si Emitter in Si Solar Cells

DONGSUN KIM,[1] CHEL-JONG CHOI,[2] and HYUNGSUN KIM[1,3]

1.—School of Materials Engineering, Inha University, 253 Younghyun-dong, Incheon 402-751, South Korea. 2.—School of Semiconductor and Chemical Engineering, Chonbuk National University, Jeonju 561-756, South Korea. 3.—e-mail: kimhs@inha.ac.kr

To improve the performance of Si solar cells after firing, it is necessary to control the thickness of the glass layers between the Ag and Si, and the formation of Ag when it recrystallizes into the Si emitter, both of which decisively influence the performance of the cell. In this study, the effect of the physical properties of the frits on the contacts between Ag and Si is verified. Interfaces of Ag electrodes/glass layers/Ag recrystallized into n^+ emitter are formed when using high-fluidity frits. On the other hand, as the viscous flow of the frits slows as the temperature increases, an interface structure formed of Ag/thin glass/SiN_x layers results, with the formation of Ag nanoprecipitates in the glass layers. Our results suggest that the viscous behavior of frits under increasing temperatures leads to the formation of distinct interfaces between Ag electrodes and Si.

Key words: Interfaces, thermal properties, glass, Si_3N_4

INTRODUCTION

It has been reported that bismate glass systems can be applied to Ag pastes on the top side of electrode materials to achieve outstanding Si solar cell performance.[1,2] The interface structures between the Ag electrodes and the Si emitter need to be controlled to optimize the performance of the resulting Si solar cells.[3] In particular, the glass frits play a decisive role in the contacts between Ag and Si during firing.[4] The viscous flow of the frits influences the thickness of the glass layers, the formation of Ag crystallites between the Ag and the Si wafer, and the depth that the Ag penetrates into the n^+ emitter during firing, all of which affect the series resistance and shunt resistance of the cell.[5] Controlling these factors is crucial when seeking to improve the electrical properties of solar cells. Therefore, the physical properties of glass frits in Ag pastes should be properly designed by optimizing the composition of the frits to maximize the performance of Si solar cells.

Different models of contact formation between Ag electrodes and Si solar cells with PbO glass systems have been extensively studied and reported.[6] The current path from Si to the Ag electrode is summarized as follows: direct interconnection between the Ag electrode and Si,[7] tunneling between Ag recrystallites partly formed in the n^+ emitter and the ultrathin glass layer,[8] and multistep conduction through metal precipitation in the glass.[9,10] However, there are few fundamental studies on the interface structures between Ag and Si with bismate glass systems in Ag pastes. Therefore, fundamental studies need to be conducted regarding contact formation in bismate glass systems.

In this study, we examine the interface structures between Ag and Si while considering the viscous flow of bismate glasses at high temperatures. The viscous flow of frits at high temperatures profoundly influenced the glass layers formed between the Ag electrodes and Si, as well as the formation of Ag recrystallites on the n^+ emitter and their penetration into the emitter. The results of this study

(Received September 9, 2012; accepted December 31, 2012; published online February 21, 2013)