ISSN 1063-7397, Russian Microelectronics, 2020, Vol. 49, No. 1, pp. 55–61. © Pleiades Publishing, Ltd., 2020.
Russian Text © The Author(s), 2020, published in Mikroelektronika, 2020, Vol. 49, No. 1, pp. 58–65.

Electronic Conductivity in a P^+-Ion Implanted Positive Photoresist

A. N. Oleshkevich[a], *, N. M. Lapchuk[a], V. B. Odzhaev[a], **, I. A. Karpovich[a], V. S. Prosolovich[a], D. I. Brinkevich[a], and S. D. Brinkevich[a]

[a] *Belarus State University, Minsk, 220030 Belarus*

**e-mail: Oleshkevich@bsu.by*

***e-mail: Odzaev@bsu.by*

Received May 17, 2019; revised May 22, 2019; accepted June 4, 2019

Abstract—FP-9120 positive photoresist films 1.8 μm thick implanted with boron and phosphorus ions deposited onto the surface of KDB-10 single-crystal (111) silicon wafers by centrifugation are investigated by their conductivity and electron spin resonance measurements. It is shown that the P^+ ion implantation leads to the formation of a layer with an electronic conductivity of about $10^{-9}\ \Omega^{-1}\ cm^{-1}$. At a phosphorous implantation dose of $6 \times 10^{15}\ cm^{-2}$, the electron spin resonance spectrum contains a narrow isotropic line with a *g* factor of 2.00654 and a width of 3.83 G, which is most likely related to the formation of phenoxy radicals. As the implantation dose increases to $1.2 \times 10^{16}\ cm^{-2}$, a line with a *g* factor of 2.00264 and a width of 3.96 G is detected in the electron spin resonance spectrum, which is caused by unpaired electrons delocalized according to the π-polyconjugated system.

Keywords: photoresist, implantation, electronic conductivity, electron spin resonance, phenoxy radicals

DOI: 10.1134/S1063739719060076

INTRODUCTION

Polymers are widely used to protect discrete and integrated electronic devices against external factors and have, as a rule, good insulating properties, which ensure electric charge accumulation in the polymer exposed to electromagnetic and penetrating radiation. At a certain critical value, an electrical breakdown can occur, which can cause a failure in the operation of individual electronic circuit components and the entire device [1, 2]. When choosing materials for compensating the induced charges, it should be taken into account that most polymer materials (polyimide, polytetrafluoroethylene, polystyrene, etc.) are hole dielectrics, while the charge drain requires materials with electronic conductivity. In such materials, the injection currents which allow charges to efficiently drain from a dielectric to metal elements (outputs) can be induced [3].

Ion implantation is one of the main methods for forming device structures. It can be used to create both surface and buried layers with different conductivities [4, 5]. Since polymer photoresists are widely used in electronic production and the main material in manufacturing semiconductor devices is silicon, the possibility of using ion implantation to form layers with electronic conductivity was studied on commercial FP-9120 photoresist films deposited by centrifugation onto silicon wafers. It is important that this photoresist is based on phenol formaldehyde resins with strong radiation resistance [6].

Abbreviations: ESR, electron spin resonance; CSP, conductive silver paste.

The aim of the study is to investigate the possibility of creating a diazoquinone-novolak FP-9120 photoresist layer with the controlled electronic conductivity using ion implantation.

EXPERIMENTAL

Films 1.8 μm thick of an FP-9120 positive photoresist, which is a composite of the photosensitive orthonaphthoquinondiazide and phenol formaldehyde resin, were deposited onto the Si surface by centrifugation at a centrifuge speed of 2900 rpm. The substrates were KDB-10 single-crystal silicon wafers 100 mm in diameter with the (111) orientation. Before the formation of a photoresist film, the silicon wafers were subjected to conventional surface cleaning in organic and inorganic solvents. The rotation time of the centrifuge was 40 s. After depositing the photoresist onto the working side of the wafer, the latter was dried for 50–55 min at a temperature of 88°C. The photoresist film thickness was controlled with an MII-4 microinterferometer at five fixed points lying on two mutually perpendicular diameters on each wafer.

The film's conductivity was measured by the van der Pauw method. Electric contacts to the implanted photoresist side were formed from an epoxy-based conductive silver paste (CSP). The contact diameter was not more than 1 mm. For the convenience of measurements, copper wires were inserted into the contacts during the polymerization of the CSP.

The ESR spectra of the photoresist were recorded on a RadioPAN SE/X-2543 radiospectrometer with