The Electrical Nature of Au-hyperdoped Si

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Hyperdoping of Si with deep level impurities can realize Si-based near-infrared photodetectors through the introduction of an intermediate band (IB) in the Si bandgap. These materials are typically fabricated by ion implantation of suitable impurities followed by pulsed laser melting (PLM) to achieve the impurity concentrations required to form an IB.

Among the various deep level impurities explored to date, Au is the only impurity that can be hyperdoped homogenously in monocrystalline Si at the required concentrations [1]. However, despite showing broadband near-infrared optical absorption and photoresponse, fabricated Au-hyperdoped Si detectors have extremely low quantum efficiencies (< 0.01%) [2], most likely due to poor carrier transport properties within the hyperdoped layer [3, 4]. In our recent work, we suggested that the near-infrared light detection efficiency in Au-hyperdoped Si based devices can be improved by optimized device architectures [4]. This requires accurate knowledge of the electrical properties of the Au-hyperdoped layer. It was previously suggested that Au-hyperdoping in n-type Si can result in a type conversion to p-type [2, 3, 5].

In this work, we present Hall effect measurements performed on Au-hyperdoped Si samples in a van der Pauw configuration. A wet etch recipe was developed to etch away surface segregated Au from the PLM, and Rutherford backscattering spectrometry with channeling analysis (RBS-C) was used to measure the Au depth distribution before and after etching. Our experiment provided two surprising and important observations: (1) Au-hyperdoped Si is highly resistive (semi-insulating) and does not result in n-to-p-type conversion and (2) the anomalous p-type nature of Au-hyperdoped Si reported in the literature originates from a Fermi-level pinning effect at the surface of the samples due to accumulated Au atoms at the surface [6].

[1] S. Q. Lim et al., J. Appl. Phys. **129**:065701 (2021).
[2] J. P. Mailoa, et al., Nat. Commun. **5**:3011 (2014).
[3] S. Q. Lim et al., J. Appl. Phys. **126**:224502 (2019).
[4] S. Q. Lim et al., APL Materials **8**:061109 (2020).
[5] H. Weman et al., J. Appl. Phys. **65**:137 (1989); M. Valdinoci et al., IEEE Trans. Electron. Dev. **43**:2269 (1996).
[6] S. Brotherton, J. Appl. Phys., **42**:2085 (1971); S. Q. Lim, PhD thesis, the Australian National University (2021).