High sensitivity infrared absorption spectroscopy and infrared defect dynamics of silicon crystal (22) Standard measurement procedure of N-complexes

シリコン結晶の高感度赤外吸収と赤外欠陥動力学(22)窒素複合体の濃度測定標準手続き

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Introduction

Now, nitrogen concentration is measured by local vibration mode (LVM) infrared absorption (IR) of NN pair rings [1]. The standard procedure was established as the JEITA Standard in 2009 [2, 3]. There are, however, other complexes, NO pair rings, forming shallow thermal donors (STD), dominant in low [N] samples [4]. Their concentration is measured by carrier concentration or by far IR absorption due to electronic transition [5]. We found and assigned its LVM IR absorption [6]. Two IR absorption bands at 551 and 688 cm⁻¹ [7, 8] were rediscovered recently in irradiated and annealed Si [9] and in asgrown CZ and FZ-Si, and identified as N_i and VVNN, respectively [10]. Different complexes show different behavior, especially in grown-in defect formation. It is necessary now to measure them separately and totally. The following procedures is proposed to add to the existing JEITA Standard which has been examined to be established as the SEMI Standard previously.

1 NN pair and its O attachments

There are 7 LVM IR bands due to NN (766, 963 cm⁻¹) [1], NNO (801, 996, 1027 cm⁻¹) [8, 11] and NNOO (810, 1018 cm⁻¹) [8, 12] pair rings. The measurement procedure was established in JEITA Standard in 2009.

2 NO pair and its O attachments

2-1, 2 Carrier concentration and far IR absorption

STD has been suggested to be NO pair ring and its O attachments. Measurement procedure by <u>carrier concentration</u> and <u>far IR absorption at 240 and 249 cm⁻¹</u> was proposed [5, 13] and used now. Two unidentified complexes are used.

2-3 LVM IR absorption

LVM IR absorption by NO pair group was found at <u>855, 973 and 1002 cm⁻¹</u>. 973 and 1002 cm⁻¹ absorption was assigned to <u>(NO)OO</u>, and later absorption at 855 and <u>1065 cm⁻¹</u> [14] was assigned to <u>ONO</u> double ring [15]. N concentration dependence of these IR absorption was examined. There are 7 possible configurations, <u>(NO)O₀₋₂ and (ONO)O₀₋₂ [16]</u>.

3 Ni and VVNN

IR absorptions at about 550 and 690 cm⁻¹ have been observed in Si after ion implantation and annealing, but not assigned. Recently they have been rediscovered in as-grown CZ and FZ Si, respectively [9, 10]. Their peak absorptions are 1/3 and 1/15 of NN absorption, respectively [17].

Tentatively, the following absorption coefficient and the sum give individual and total complex concentrations using the established conversion coefficient *k* of 1.83×10^{17} /cm² [3, 18].

 $(\alpha_{766} + \alpha_{801} + \alpha_{810} + \alpha_{551} + \alpha_{688} + \alpha_{973} + \alpha_{855}) \ge k$

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