Determination of Avogadro Constant and the Required Quality of the Silicon Single Crystal

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The Avogadro constant is measured by the X-ray Crystal Density (XRCD) method. In the method, the molar volume and the unit cell volume of a pure silicon in the perfect sinle crystal are measured and the ratio of them becomes Avogadro constant N_A. The molar volume is derived by the ratio of the molar mass M and the density ρ. The molar mass M is deduced from the atmic abandunce measured by the mass spectrometer. The unit cell volume is deduced from the measurement of the lattice spacing in the 220 direction, d_{220}, and becomes $8^{1/2} d_{220}^3$. The full expression becomes
$N_A = M/(8^{1/2}\rho d_{220}^3)$.
In the history measurements have been performed using the silicon ingot produced from the raw material of natural abundance. In the middle of the 2000s, we concluded that the measurement uncertainty could not be improved further by measureing the silicon of natural abundances and we started the new project of measurement using the isotopically enriched silicon, ^{28}Si.
As a result of the project we obtained the uncertainty of 3×10^{-8} for the Avogadro constant N_A. As the measurement uncertaintie is limited by the pureness of the sample many evaluations are performed as follows during this project. Impurity concentrations are measured by the infrared spectroscopy and the concentrations are used for the thermal expantion comensation, vacancies are evaluated to be $3.3(1.1)\times10^{14}$cm^{-3} by the positron annihiration method, voids are estimated by the laser scattering tomography and no voids bigger than 30 nm are detected with the detection limit, the hydrogen contamination of the sample was tested by the deep level transient spectroscopy and no hydrogen was found to within the 2×10^{13} cm^{-3} detection limit, the homogeneity of the lattice spacing of the silicon ingot was less than 10^{-8} by the measurement in the BL3C in KEKPF.

Detailes are presented in the presentation.