北京大学量子材料科学中心

International Center for Quantum Materials, PKU

Seminar

Introduction of Scanning nonlinear dielectric microscopy

Yasuo Cho

Tohoku University

Time: 10:00 am, Oct. 10, 2023 (Tuesday)

时间：2023年10月10日 （周二）上午10:00

Venue: Room w563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

Scanning nonlinear dielectric microscopy (SNDM) was invented in 1994 by Prof. Ysuo Cho in Yamaguchi, Japan. Originally it was developed for investigating ferroelectric and dielectric materials with rather small nonlinear dielectric effects through the detection of capacitance variations caused by an applied voltage, that is, $\mathrm{d}C/\mathrm{d}V$. Thus since its early days, SNDM has featured a high sensitivity to capacitance variation, on the order of $10^{-22}F/\sqrt{Hz}$. SNDM can easily measure nanoscale ferroelectric domains under ambient conditions and even atomic-scale dipole moments under ultrahigh vacuum conditions. Moreover, as an application of SNDM to next generation ultrahigh-density memory devices beyond the magnetic hard disk drive (HDD) and semiconductor flash memory, an investigation of ultrahigh-density ferroelectric data storage based on SNDM has been extensively investigated.

As SNDM has a high sensitivity to capacitance variation, it is also very effective at characterizing semiconductor materials and devices. It can easily distinguish the dopant type (PN) and has a wide dynamic range of sensitivity to both low and high concentrations of dopants. It is also applicable to the analysis of compound semiconductors with much lower signal levels than Si. We can avoid errors due to the two-valued function (contrast reversal) problem of $\mathrm{d}C/\mathrm{d}V$ signals using $\mathrm{d}C/\mathrm{d}z$-SNDM. Extended versions of SNDM have been developed, such as super higher-order SNDM, local-deep-level transient spectroscopy, noncontact SNDM, and scanning nonlinear dielectric potentiometry. The favorable features of SNDM originate from its significant sensitivity.

This technique will meet the needs of those researchers in the industry, as well as academics and students, involved in the fields of ferroelectrics, dielectrics, semiconductors, and scanning probe microscopy. It will help those intending to investigate the ferroelectric nanodomain structure, which cannot be resolved by conventional piezo response force microscopy (PFM), and the atomic dipole moment, which cannot be distinguished by conventional Kelvin probe force microscopy (KPFM), to realize ultrahigh-density ferroelectric data storage with much higher memory densities compared to flash memories and magnetic HDDs, to visualize the dopant distribution in the fine structure of state-of-the-art mutualized semiconductor devices, to visualize linear permittivities with higher resolution than other capacitance microscopies, to perform operand measurements of the carrier distribution of working semiconductor devices, to visualize the depletion layer distribution of semiconductor devices that cannot be measured by other methods, to visualize the two-dimensional trap (interface state of density, D_{it}) distribution at the MOS interface, which has never been visualized by other techniques, and to measure real-time (ns range) carrier movement in semiconductor materials and devices. The SNDM gives new insight into the material and device physics of ferroelectrics, dielectrics, and semiconductors, which has proven hard to obtain by other methods.

About the speaker

Yasuo Cho, is a professor at Tohoku University, Japan. He graduated in 1980 from Tohoku University in electrical engineering department. In 1985 he became a research associate at Research Institute of Electrical Communication, Tohoku University. In 1990 he received an associate professorship from Yamaguchi University. He then became an associate professor in 1997 and a full professor in2001 at Research Institute of Electrical Communication, Tohoku University. During this time, his main research interests included nonlinear phenomena in ferroelectric materials and their applications, development on novel evaluation methods of semiconductor materials and devices based on scanning nonlinear dielectric microscopy (SNDM), and research on using the SNDM in next-generation ultrahigh-density ferroelectric data storage (SNDM ferroelectric probe memory).

http://icqm.pku.edu.cn

Host: 江颖<yjiang@pku.edu.cn>