1　Materials Properties

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Materials Properties conducts research and education about the theory and application of mechanical, electric, magnetic, optical and thermal characteristics of materials.

Studies of Infrared Detecting Semiconductors

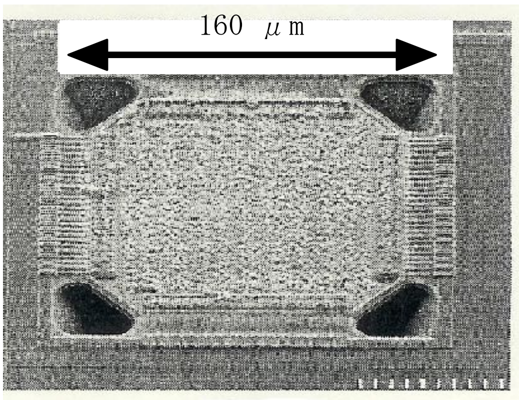
Jun Morimoto

Infrared sensors are divides into two categories, quantum type and thermal. Quantum (cooling type) IR sensors have excellent sensitivity and response, howewvwe, they are very expensive and their application is limited. Thermal (non-cooling type) IR sensors, such as pyroelectric, bolometer and thermopile, have been widely developed and are used extensively because of good performance and lower cost.

We are interested in10 μm range of infrared detecting materials. The mid-gap levels in HgCdTe, which affect the sensitivity or the life time of these quantum type devices, have been widely studied. Whereas, the thermopile type Si-Ge semiconductor system, which uses the anomalous large thermoelectric motive force, has only recently been developed. This non-cooling type sensor system is very promising in the areas of CMOS compatibility, device manufacturing, signal processing, low power consumption and low cost. [1)]

The electrical, optical and thermal characteristics of infrared detecting semiconductors have attracted a great deal of attention. These studies have been conducted in collaboration with TRDI of the Ministry of Defense.

1) J. Morimoto: Defense Technology Journal, Vol. 26, No.12 (2006) 12.



SEM observation of thermopyle type sensor

Application of Compound Semiconductors (SiC) for Power Devices

Jun Morimoto

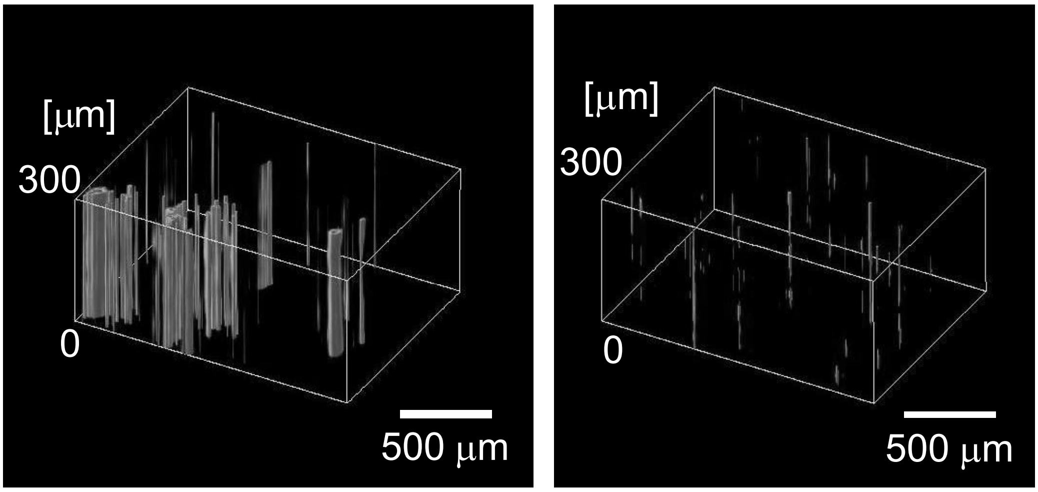
Much attention is paid to the wide band gap semiconductors, especially to SiC which are substituted for Si or GaAs as the new generation materials. SiC has superior characteristics to Si, such as wide band gap (three-fold), high breakdown field (ten-fold), high saturation drift velocity of carrier (two-fold), and high thermal conductivity (three-fold).

Compared with other wide gap semiconductors, SiC has the ability of conductivity control and processing of oxide layer for manufacturing of MOS structure.

SiC device or SiC based GaN device can increase the power capacity and operation frequency. Additionally, SiC power devices are the key to improving the performance of various vehicles. [1)]

The research is focused on the electrical, optical, and thermal characterization of impurities or defects in the SiC bulk single crystal.

1) J. Morimoto: Defense Technology Journal, Vol. 28, No.2 (2008) 22.



(a) (b)

Distribution of micro pipe defects in the SiC single crystals detected by 3-dimensional infrared light scattering tomograph.

(a) crystal includes many micro pipe defects. (b) crystal includes less defects.

Studies of Next Generation High-efficiency Solar Cells using Nano-technologies.

Hisashi Miyazaki and Jun Morimoto

Compound semiconductor thin-films are promising materials for high-efficiency solar cells. Recently, the research activities of compound thin-film solar cells have shifted into polycrystalline chalcopyrite $CuInSe_2$-related materials, which have high absorption coefficient, direct bandgap and high stability. Other advantages of this material are the possibility of band gap engineering by $Cu(InGa)Se_2$, $Cu(AlIn)Se_2$ and $CuIn(SSe)_2$. Figure 1 shows the typical structure of CIGS thin-film solar cells. Absorber layer of CIS-related materials is deposited by multi-source vacuum evaporation. Buffer layer of CdS, ZnO, ZnS and related II-VI compounds is deposited by chemical bath deposition. Window layer of metal-doped ZnO is deposited by sputtering or CVD process.

Recently, solar cells based on quantum effects attract many researchers attention, such as inter-band cells, hot carrier cells, up-conversion cells, or all silicon tandem cells. Si quantum dots structure is the most important film to realize all silicon tandem solar cells. Figure 2 shows the Si quantum dots in amorphous-SiC matrix. We try to prepare the $Si_{1-x}C_x$/SiC ($0 \leq x \leq 0.5$) superlattice structure onto quartz and silicon substrate. The deposition of superlattice films was annealed to prepare Si quantum dos in amorphous SiC matrix. This research is progressive approach for "third-generation photovoltaics".

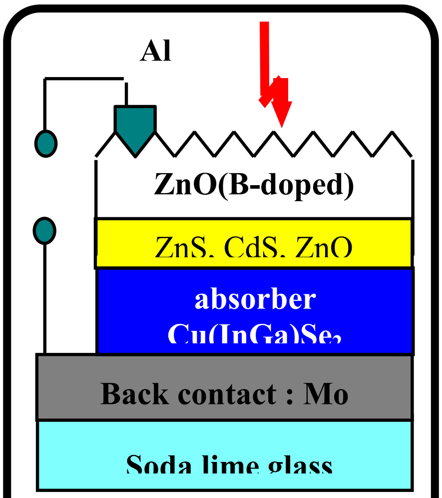


Fig 1. Second-generation CIS thin-film solar cell

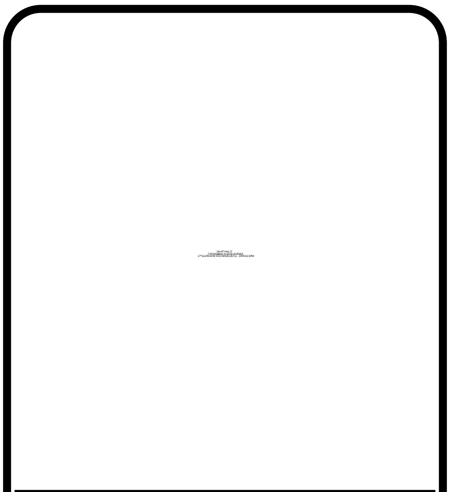


Fig 2. Si quantum dot in a-SiC matrix. M. Zacharias, et. al. APL, **80**, 4 (2002) pp.

My motto is that “EXPERIMENTS ARE INTERESTING AND ATTRCTIVE”.

So you enjoy experiments, that is; synthesis (preparation) of samples (or materials), determination of crystal structure and characterization of some useful properties that you measure them in our laboratory of material characterization.

I concern inorganic compounds and ceramics; especially sulfides, oxides, nitrides and so forth.

First, sulfides have been prepared in order to search for new phases, particularly unkown compounds about crystal structure. We have a lot of useful apparatuses of material characterization; X-ray fluorescence spectrometer (XRF), powder X-ray diffractometer (XRD), and also single crystal X-ray diffractometers (ccd type, imaging plate type, etc.). I am specialist of X-ray crystal structure analysis. Couldn’t you join us to solve a crystal structure of unkown compounds?

Second, I love rare earth atoms. Recently, we have focused on rare earth phosphors, especially red ones ($Eu_2W_2O_9$, $Eu_2W_3O_{12}$, etc.), or colorful ones like a rare earth thiogallate. Although red color of 4f-4f transition is beautiful, color of 5d-4f transition is variety of different rainbow ones. It’s amazing! Wouldn’t you look at them with us?

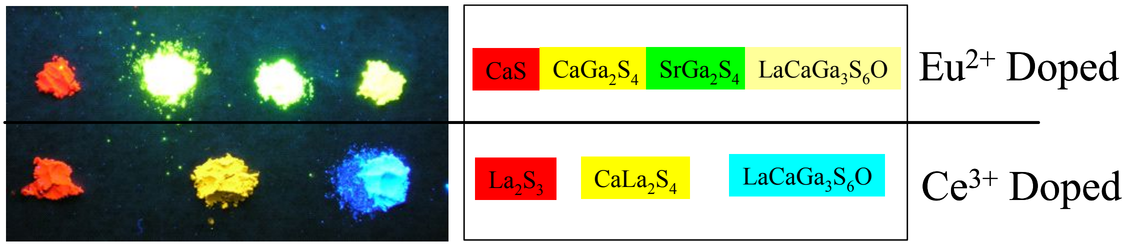
Third, we have studied thermoelectric conversion materials for twenty years. At the first time, we sintered silicon carbide (SiC) based ones. Nowadays we have changed to grain boundary controlled tungsten (W) sintering ones. At the first stage, we have found that scheelite ($CaWO_4$) is effective as a grain boundary. Now optimum calcining condition have been controlling. I wish we will get a good results. So would you try and get a best sintering one? I am waiting for you coming!

In the past, we made ornaments using interstitial compounds; i.e. gold colored titanium nitride (TiN), bronzy titanium carbonitride ($TiC_{0.3}N_{0.7}$), and platinum vanadium nitride (VN). They are very hard materials (Vickers hardness is over 8) and their shining keep up. Let’s make up them to get an enduring brilliance.

We are always using electrical furnaces; very-high temperature carbon heating one (up to 3273 K), gas-pressure (GS) and hot-press (HP) sintering one (up to 2573 K), box-type one (up to 1973 K), tube-type one (up to 1973 K), one for dewax or carbonization (up to 1273 K), and also ceramics one using a silica tube method.

Other evaluation equipments, we are using, are following; SEM/EDX, TEM, EPMA, XPS, ICP-AES, ESR, Raman, FT-IR, fiber multi channel spectrometer,

thermoelectric power measurement apparatus, apparatus measuring fluorescence lifetime (using measurements of excitation and emission spectrum), and so on.
(Supervisor: associate professor Atsushi ARUGA)



Rare Earth Phosphor

Associate Professor: Hiroshi Abe

Room temperature ionic liquids (RTILs) based mixtures

Hidden water behaviors are enhanced in RTIL-water mixtures. The phase changes depend on water concentration sensitively.

Electrochemical oscillation in Electro HydroDynamics (EHD) phenomena

EHD convections are induced by the applied voltage. Under some experimental conditions, electrochemical oscillation is observed. Moreover, the phenomena are simulated successfully by introducing electric double layer.