ISSP ワークショップ

Polar Oxides for Energy Conversion

日時：2013 年 6 月 26 日(水)　13：00〜20：00
場所：東京大学物性研究所６階大講義室

提案者
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6 月 26 日の午後から半日の期間で、エネルギー変換に関連した材料の科学、その開発に従事している 40 人を超える研究者を集め、物性研セミナーを開催した。エネルギー変換を目指す材料というと、半導体から誘電体、熱電材料、熱弾性材料などの広い材料を網羅している。そのため、本セミナーでは新しい極性結晶の開発から、酸化物薄膜の合成手法の開発、酸化物界面の構造や電子物性の評価に至るまで幅広い領域をカバーした。ほとんどの発表において新しい酸化物を創製するためのアプローチ、そしてエネルギー変換に関連したデバイス応用に向けた機能性酸化物を合成するための新しい手法を提案している。また、酸化物材料の発表に加え、新しい熱弾性金属材料の開発に関する発表も行われ、固体素子を用いた冷却技術についても紹介された。エネルギー応用に関連した材料のライフサイクルを考えさせられる発表であった。

Program

13:00　リップマー　ミック　（東京大学物性研）　はじめに

Chair :　リップマー　ミック

13:05　藤本 憲次郎　東京理科大学理工学部工業化学科　講師
“層状およびトンネル状酸化物の窒素酸化物吸蔵特性”

13:30　松本 祐司　東北大学　工学研究科応用化学専攻　教授
“酸化物半導体の真空電気化学”

13:55　大島 孝仁　東京工業大学　理工学研究科応用化学専攻　助教
“遷移金属酸化物の電子構造制御による光エネルギ変換材料への展開”

14:20　菅　大介　京都大学　化学研究所　助教
“酸素八面体の連結性を利用したペロブスカイト酸化物の相制御”

14:45　近松　彰　東京大学　理学部化学科　助教
“層状鉄酸化物のトポタクティック合成”

廣瀬　靖　東京大学　理学部化学科　助教
“酸窒化物強誘電体薄膜”

15:10-15:35 休憩

Chair :　松本 祐司

15:35　小塚 祐介　東京大学工学系研究科物理工学専攻　助教
“分極不整合界面における高移動度二次元電子ガスの量子伝導”

16:00　高橋 竜太　東京大学物性研究所　助教
“焦電性を用いた極性結晶の評価：マグネタイトとダブルペロブスカイト結晶”

16:25　竹内 一郎　University of Maryland, Department of Materials Science and Engineering, 教授
“Elastocaloric cooling: phenomenon, materials, devices, and comparison with other solid state cooling technologies”

16:55　鯉沼 秀臣　東京大学新領域創成科学研究科　特任教授
“Stem cell があるなら、Stem material, Stem energy は?”

17:25　松本 祐司　おわりに

18:30　懇親会 @ カフェテリア

Summary of presentations

層状およびトンネル状酸化物の窒素酸化物吸蔵特性

藤本 憲次郎（東京理科大）

Burning fuels at high temperature produces environmentally harmful nitrogen oxides. Although catalytic conversion is generally used in power plants or other pollution sources for reducing NO_x emissions, the catalysts generally include precious metals. New oxide materials in the AMO_x family, with A = Li, Na, K, Rb, Cs and M = Fe, Sn, Ti, may over sufficient NO_x conversion efficiency to compete with precious metal catalysts.

酸化物半導体の真空電気化学

松本 祐司（東北大）

Electrochemical analysis is generally used to identify catalytic reactions taking place at liquid-solid interfaces. The technique is also useful for the analysis of surface electronic structures of semiconducting materials. In this study, a high-vacuum thin film growth system for oxides has been combined with an in-situ electrochemical cell, where single-crystal thin film samples can be repeatedly characterized electrochemically and processed in vacuum without exposure to air, allowing for accurate analysis of oxide semiconductor surfaces.

遷移金属酸化物の電子構造制御による光エネルギ変換材料への展開

大島 孝仁（東京工大）

Various wide-gap oxide semiconductors have excellent chemical stability in water and are therefore considered as possible photocatalytic materials for solar water splitting. However, due to a large bandgap, most such semiconductors can only absorb ultraviolet light. This work shows that it is possible to arbitrarily tune the bandgap of an oxide semiconductor by co-doping with several transition-metal cations, such as Cr and Fe in $SrTiO_3$, that allow for independent shifting of both valence and conduction band edges. Reasonably high light absorption efficiencies can be achieved in this way in the visible spectral range.

酸素八面体の連結性を利用したペロブスカイト酸化物の相制御

菅　大介（京都大）

Unit cell scale lattice distortions in oxides can have a large effect on the functional properties of interface layers. Analysis of bright-field scanning transmission electron microscopy images can be used to extract the depth profile of lattice distortions, such as octahedral rotations at mismatched interfaces. Insertion of lattice-matching interface layers, even if only a single unit cell thick, can be effective for lattice distortion control in oxide heterostructures.

層状鉄酸化物のトポタクティック合成

近松　彰（東京大）

The band gap of an oxide semiconductor is a critical parameter in photovoltaic and photocatalytic materials. In many cases it is the hybridization of the transition metal 3d orbitals with the oxygen 2p orbitals that determines the location of the valence band edge. An interesting material system in this regard is the infinite-layer analog $SrFeO_2$, which can be synthesized by annealing $SrFeO_{3-\delta}$ in the presence of CaH_2, effectively shifting the bandgap to 1.3 eV.

酸窒化物強誘電体薄膜

廣瀬　靖（東京大）

Novel polar oxides may offer interesting new ways of designing heterostructures with suitable built-in fields for photocarrier separation or accumulation. In this regard, oxynitrides are an interesting family of compounds that can have fairly low bandgaps and show ferroelectric polarization. As an example, $SrTaO_2N$ has been recently shown to have a bandgap absorption edge at around 600 nm, yielding a yellow color while also showing room temperature ferroelectricity.

分極不整合界面における高移動度二次元電子ガスの量子伝導

小塚 祐介（東京大）

Low carrier mobility is often the main limiting factor in efficient photogenerated charge extraction from oxide semiconductors. In this regard, it is interesting to look at oxide systems that can support very high carrier mobilities, such as ZnO. The current record mobility achieved in ZnO is approaching 10^6 cm^2/Vs at low temperature and thus competes with the best non-oxide semiconductors. The growth techniques used for fabricating exceptionally high-mobility oxide thin films and heterostructures were reviewed.

焦電性を用いた極性結晶の評価：マグネタイトとダブルペロブスカイト結晶

高橋 竜太（東京大）

Polar oxides can be valuable in designing the built-in field of an oxide junction. However, in many cases, particularly for thin films, polar materials may show large leak currents, making it challenging to measure the polarization or even observe ferroelectric switching in very thin films or interface regions. For this reason, pyroelectric zero-bias characterization can be effective. Several example cases are reviewed here, including magnetite below the Verwey temperature, a double-perovskite $La(Ni,Mn)O_3$, and BeO.

Elastocaloric cooling: phenomenon, materials, devices, and comparison with other solid state cooling technologies

竹内 一郎（University of Maryland）

Solid-state cooling can potentially be more efficient and reliable than traditional gas-liquid refrigerators, particularly in usage cases that need to be maintenance free. Solid-state elastocaloric cooling may offer a way to achieve this, where heat can be stored, transported, and released upon mechanically straining and relaxing a shape memory alloy wire or foil. In principle, the technique may be applied to large scale refrigeration but may also be useful for micro-scale heat handling.

Stem cell があるなら、Stem material, Stem energy は?

鯉沼 秀臣（東京大）

In an oxidizing environment, such as the surface of the Earth, oxides are the most abundant materials and can be viewed as a 'ground state' for matter. From a general energy consumption point of view, materials synthesis generally starts from an oxide and ultimately returns to an oxide. From a general material life cycle point of view, there are thus significant advantages in using oxides as functional components in large-scale energy conversion applications.