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Form 3

Abstract of Thesis

Name	(NGUYEN THI VAN ANH)
Title	Electrical transport properties in phase-separated manganite studied by terahertz time domain spectroscopy (テラヘルツ時間領域分解分光による電子相分離状態マンガン酸化物の伝導特性の導出)

Abstract of Thesis

The transition metal oxides with strongly correlated electrons have emerged as exotic materials with various functionalities such as the colossal magnetoresistivity in manganites. Of particular interest is a typical perovskite manganite (La,Pr,Ca)MnO_3 (LPCMO) which exhibits the insulator - metal transition (IMT) originating from the coexistence of metal and insulator domains in a nanometer scale. Interestingly, peculiar functionalities can be expected in the nanometer scale mixed-phase materials in which the electronic domains were confined. To understand their nanopeculiar conductive property, the quantitative estimation of domain evolution which shows the temperature-induced fraction change of metallic domain ($X(T)$) in the coexistence phenomena becomes extremely important. Moreover, the estimation of dc conductivity ($\sigma_{dc}(T)$) for nanoscale electronic domains is also vital not only in elucidating the IMT behavior, but also in designing new functional oxide nano electronics devices.

In this thesis, I have successfully developed an efficient technique to investigate the transport dynamics in nanoscale phase-separated materials by taking advantage of terahertz time domain spectroscopy (THz-TDS). My achievements are listed in following parts:

(1) I established the technique to investigate electrical transport properties, i.e., the simultaneous evaluation of $X(T)$ and $\sigma_{dc}(T)$ in a LPCMO film by the THz-TDS. I obtained the THz conductivity behavior at different temperatures ($\sigma_{THz}(\omega, T)$ curves) for the film, and then I proposed an original "insulator-metal composite model" to successfully explain the change of $\sigma_{THz}(\omega, T)$ behavior through the IMT. This model enabled us to estimate the electrical transport properties for a mixed-phase oxide film in a non-contact manner. This technique is applicable for other mixed-phase nanostructured materials.

(2) I successfully estimated the electrical transport properties in a 100-nm-width LPCMO nanowires sample through the IMT using the THz-TDS. By aligning the high-density nanowires parallel to the polarization direction of THz pulse, I obtained their characteristic conductivity behavior $\sigma_{THz}(\omega, T)$. The $X(T)$, estimated by fitting $\sigma_{THz}(\omega, T)$ curves based on my proposed insulator-metal composite model, revealed the rapid change of electronic domain from metal to insulator with increasing temperature in comparison with the conventional film sample. Simultaneously this technique enabled us to evaluate the $\sigma_{dc}(T)$ for nanowires without attaching electrodes, indicating that this is a powerful tool for study of the electrical transport properties in nanostructured materials.

(3) As a development of nanostructure fabrication, I successfully produced the manganite nanobox array structures with precise control of their wall-width down to 30 nm using an original three-dimensional (3D) nanotemplate pulsed laser deposition (PLD) technique. The X-ray photoemission spectroscopy on the manganite nanoboxes structure indicated their peculiar IMT functionality. The nano-oxides fabricated by this 3D nanotemplate PLD technique will be one of good candidates for future applications in nano-oxide-electronics.

様式7

論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

本研究では、ナノスケールの電子相分離現象を示すマンガン酸化物($(La,Pr,Ca)MnO_3$)において、テラヘルツ時間領域分解分光法を用いることにより、高度な各種電気輸送特性（ナノ金属相の伝導度、ナノ絶縁体相の伝導度、両者の混合体積比および試料全体の直流伝導度）を導出することに成功し、複雑な相転移挙動を示す同物質およびそのナノ構造体の電気伝導現象を相分離の機構に基づき明らかにした。

まず、パルスレーザ蒸着法を用い（$(La,Pr,Ca)MnO_3$エピタキシャル薄膜結晶試料を作成し、テラヘルツ伝導度の温度依存性を導出した。さらに従来の金属伝導のみを記述するDrudeモデルと絶縁相伝導のみを記述するAustin-Mottモデルを組み合わせた独自の「絶縁体-金属ナノコンポジットモデル」を提案し同物質系のテラヘルツ伝導度の温度依存性を説明することに成功した。加えて同モデルを用いた解析により、ナノ金属相の伝導度、ナノ絶縁体相の伝導度、両者の混合比（体積比）および試料全体の直流伝導度を一括して導出することに初めて成功した。次に、ナノインプリント法を用いて、高集積に（$(La,Pr,Ca)MnO_3$ナノワイヤ構造を作成し、ナノ構造形状とテラヘルツ光の偏光依存性を考慮した測定と解析によりナノ構造の電気伝導測定を非接触で実現し、薄膜とナノ構造の伝導の挙動の違いを見出した。さらにナノインプリントで作成したテンプレート基板の側面にパルスレーザ蒸着薄膜成長を行うことにより30nmサイズの壁幅を有する極小の（$(La,Pr,Ca)MnO_3$ナノボックス構造を形成することに成功した。

これらの結果を通じ、電子的複合ナノ構造を有する機能性材料に対し、非接触で高度な電気伝導度（各相の電気伝導度、それらの混合比および試料全体の直流伝導度）を計測する方法を実現し、その伝導メカニズムを明らかにした。

以上、本論文は機能性酸化物のナノ領域における新たな物性計測の実現とその物性機能解明に新たな知見を与えるものであり、博士（理学）の学位論文として価値のあるものと認める。