シンポジウム | イノベーション共創プログラム（CIP）：カーボンニュートラルへの道を拓く熱エネルギー工学

2024年3月20日(水) 9:00 ~ 11:30 A1433(14号館 [3階] 1433)

[A1433-3am] カーボンニュートラルへの道を拓く熱エネルギー工学

座長、シンポジウム関係者：甲村 長利、細野 英司、太田 道広、徳留 功一

エネルギーの最終形態である“熱”を最大限に活用することで、省エネルギーとカーボンニュートラル社会の実現に貢献できます。理論の高度化、計測技術の発展、新材料の発見など、近年の熱エネルギー工学の発展には目を見張るものがあります。本セッションでは、使う熱や廃棄される熱の量を減らす技術（Reduce）、熱を「熱のまま」再利用する技術（Reuse）、熱を「他の形態に」変換して利用する技術（Recycle）、すなわち、熱の3Rを中心に、この分野で活発に研究を展開されているアカデミアや企業の先生方にご講演を頂くことで、この分野の最新動向、課題、将来の展望などについて広く議論します。

聴講後のアンケートへのご協力をお願いいたします。

9:00 ~ 9:10

開会挨拶

日本語 依頼講演

9:10 ~ 9:40

[A1433-3am-01]

熱エネルギーのリサイクルとアップグレード

〇小林 敬幸[1] (1. 名古屋大学)

日本語 依頼講演

9:40 ~ 10:10

[A1433-3am-02]

低温再生型粘土系吸着剤を用いた熱利用システム

〇鈴木 正哉[1]、宮原 英隆[1]、万福 和子[1] (1. 国立研究開発法人産業技術総合研究所)

日本語 基調講演

10:10 ~ 11:10

[A1433-3am-03]

熱工学の進展とCNへの挑戦

〇花村 克悟[1] (1. 東京工業大学)

11:10 ~ 11:30

[3A143301-03-5add]

インキュベーションタイム

日本化学会 第104春季年会 (2024)

熱エネルギーのリサイクルとアップグレード

（名大院工 [1]）〇小林 敬幸 [1]

Thermal Energy Recycling and Upgrading

([1]*Graduate School of Engineering, Nagoya University*) 〇Noriyuki Kobayashi[1]

Thermal energy has a lower energy density than other forms of energy, making its use more costly. To promote the use of thermal energy in the future, it is important to develop technologies to recycle or upgrade the quality of heat according to the form of thermal energy, such as compounds, hot water, and hot air, and it is also essential to develop materials with the capabilities to support these technologies. It is also important to design technologies that can use thermal energy in different ways when it is stored and then dissipated. In recent years, there has been a focus on thermal storage not only for energy saving in industrial processes, but also for electric vehicles. Furthermore, large-capacity storage is also attracting attention as a method for leveling the demand for electricity from renewable energy sources. The important performance indicators for any application are heat storage density, heat charge/discharge rate, and upgradability (temperature rise and temperature fall), but these performances are often competitive. Thus, the design must take into account the heat transfer rate, mass transfer rate, and chemical reaction rate, as well as material selection.

In this presentation, the concept of these technologies, recent trends, and examples of the speakers' efforts will be discussed.

Keywords : heat, thermal energy, technology, thermal energy storage, upgrading

熱エネルギーはエネルギー密度が他のエネルギー形態と比べて小さいため，その利用コストが大きくなる．将来の熱エネルギーの利用の促進には，化合物，熱水，熱風などの熱エネルギーの形態に応じて，熱をリサイクルしたり質的向上を図るアップグレードする技術の進展が重要であり，それを支える機能を有する材料開発も不可欠である．また，熱エネルギーを貯蔵した後で放熱する際の熱の利用形態に応じた技術設計も重要である．近年では工業プロセスの省エネルギー向けのみならず，電動自動車向けの熱ストレージとしても着目されている．さらに，再生可能エネルギー由来の電力デマンドの平準化のための一つの手法として，大容量のストレージとしても注目されている．何れの用途においても重要な性能指標には，蓄熱密度，蓄放熱速度，アップグレード性（昇温，降温）があるが，これらの性能は競合的であることが多く，材料の選択とともに伝熱速度，物質移動速度，化学反応速度を考慮した設計が求められる．

講演ではそれらの技術の概念と近年の動向や演者らの取り組み実例について述べる．

低温再生型粘土系吸着剤を用いた熱利用システム

〇鈴木 正哉[1]・宮原 英隆[1]・万福 和子[1]
Heat utilization system using low-temperature regenerated clay adsorbent ([1]*National Institute of Advanced Industrial Science and Technology*) 〇Masaya Suzuki[1], Hidetaka Miyahara[1], Kazuko Mampuku[1]

We conducted a demonstration test of an offline heat transport system using HASClay, a clay-based adsorbent that can be dried at temperatures below 100 degrees Celsius, with separate heat recovery locations and heat utilization locations. At the heat recovery site, waste heat of approximately 100 degrees Celsius generated by the gas engine cogeneration system equipment in the factory was used to dry the adsorbent by introducing it into a tank filled with 5.5 tons of Hasclay. Heat utilization was carried out at a swimming center 2 km away, and a tank filled with Hasclay was transported on a large trailer. At the swimming center, the high-temperature air generated by supplying high-humidity air from the heated pool to a tank filled with Hasclay was used as a heat source to heat the 25-meter pool and supply hot water for the bathrooms. Dry air at room temperature after being used for heating was used not only to ventilate the pool ceiling and heat the pool interior, but also to prevent condensation. In this offline heat transport demonstration test, 50 round-trip operations were conducted and a heat storage efficiency of over 90% was confirmed. The swimming center is still utilizing heat, and its running costs are in the black.
Keywords : Heat transport; clay-based adsorbent; waste heat; low temperature drying; HASClay

100 度以下の低温で乾燥が可能な粘土系吸着剤ハスクレイを用い、熱回収場所と熱利用場所が異なる、オフライン型熱輸送システムの実証試験を行った。熱回収場所では、工場内のガスエンジン・コージェネレーションシステム設備にて発生する 100 度程度の排熱を用い、5.5 トンのハスクレイを充填したタンクに導入することによって乾燥させた。熱利用は、2km 離れたスイミングセンターにて行い、大型トレーラーにてハスクレイを充填したタンクを輸送した。スイミングセンターでは、ハスクレイを充填したタンクに温水プールの高湿度な空気を供給することにより発生する高温空気を熱源として、25m プールの温水加温と浴室に用いる温水供給を行った。加温に用いられた後の常温の乾燥空気は、プール天井内の換気やプール室内の暖房のみならず、結露防止としても利用された。このオフライン熱輸送の実証試験では、50 回の往復運転を行い 90%以上の蓄熱効率が確認された。このスイミングセンターでの熱利用は、今も行われており、ランニングコストは黒字となっている。

Advances in Thermal Engineering and Challenge to Carbon Neutrality

(*School of Engineering, Tokyo Institute of Technology*) ○ Katsunori Hanamura
Keywords: Thermal Contact Resistance; Heat Flux; Energy Conversion Efficiency; Phonon Engineering; Molecular Dynamics

For protection of global warming, many challenging researches for reduction of emission of carbon dioxide are conducting in thermal engineering from macroscopic and microscopic aspects though not directly as a DAC (Direct Air Capture). They are focusing on decrease in thermal resistance, increase in heat flux and energy conversion efficiency using phonon or photon engineering and molecular dynamics associated with nanoscale technologies and measurement skills.

Heat transfer is based on transport of vibrational motion waves (Phonons) with a various frequency. Using a nanoscale hall array (phononic crystal) in Fig.1(a), the frequency and the direction of Phonons, i.e., the heat flux can be controlled in a thin substrate. In an atomic scale, a superlattice structure made alternatively by two atomic GaN layers and two atomic AlN layers at the interface between a GaN semiconductor and a diamond heat spreader produces a spontaneous piezo-electric coherent wave transport to increase the heat flux to remove the hot spot generated around an area close to the Drain in the HEMT (High Electron Mobility Transistor) device as shown in Fig.1(b). In molecular and polymer scales, Triptycene-OH structure made on an Au surface provides a low thermal contact resistance since the water molecules intercalate into the clearance of the structure of the SAMs (Self Assembly Materials) to increase a chance of energy transport as shown in Fig.1(c). The measurement of molecular-level thermal properties of the SAMs is developed successfully with a high resolution through near-field radiation effect depending strongly on the distance between the top surface of molecules and a sharp probe edge as shown in Fig.1(d). Using a TWA (Thermal Wave Analysis) method, the thermal diffusivity of the sample with only a sub-millimeter size can be measured as shown in Fig.1(e). In Fig.1(e), the thermal diffusivities of an Erythritol-COF (Covalent Organic Framework) and a Mannitol-COF could be measured for thermal storage materials with a high heat transfer framework structure. In addition, a 13-Phage virus will become a candidate for high thermal diffusivity electric-insulators by an arrangement of orientation and a choice of decorating molecules as shown in Fig.1(f). For generation of electricity, a solar TPV (Thermo-Photo-Voltaic) system provides a high impact for the carbon neutrality. In this system, a tungsten emitter temperature rises by a concentrated solar energy, then the thermal radiation emitted from the tungsten emitter surface is converted into electricity, depending on bandgaps of the top and the bottom semiconductors as shown in Fig.1(g). On the other hand, thermal radiation with a long wavelength is almost reflected by the surface of Au-mirrorlike back electrode. Relating to this system, spectral control of near-field radiation by a pillar array structured surface is conducting as shown in Fig.1(h). Using the spectral control of radiation, a temperature of a thin film made of silica beads in a transparent plastic matrix on an Ag layer becomes lower than the atmospheric one even in day-time as shown in Fig.1(i).

Many researches for carbon neutrality are successfully developed in a range of laboratory-scale. However, it is not easy to install those ideas into practical systems as a quantitative contribution for reduction of emission of carbon dioxide.

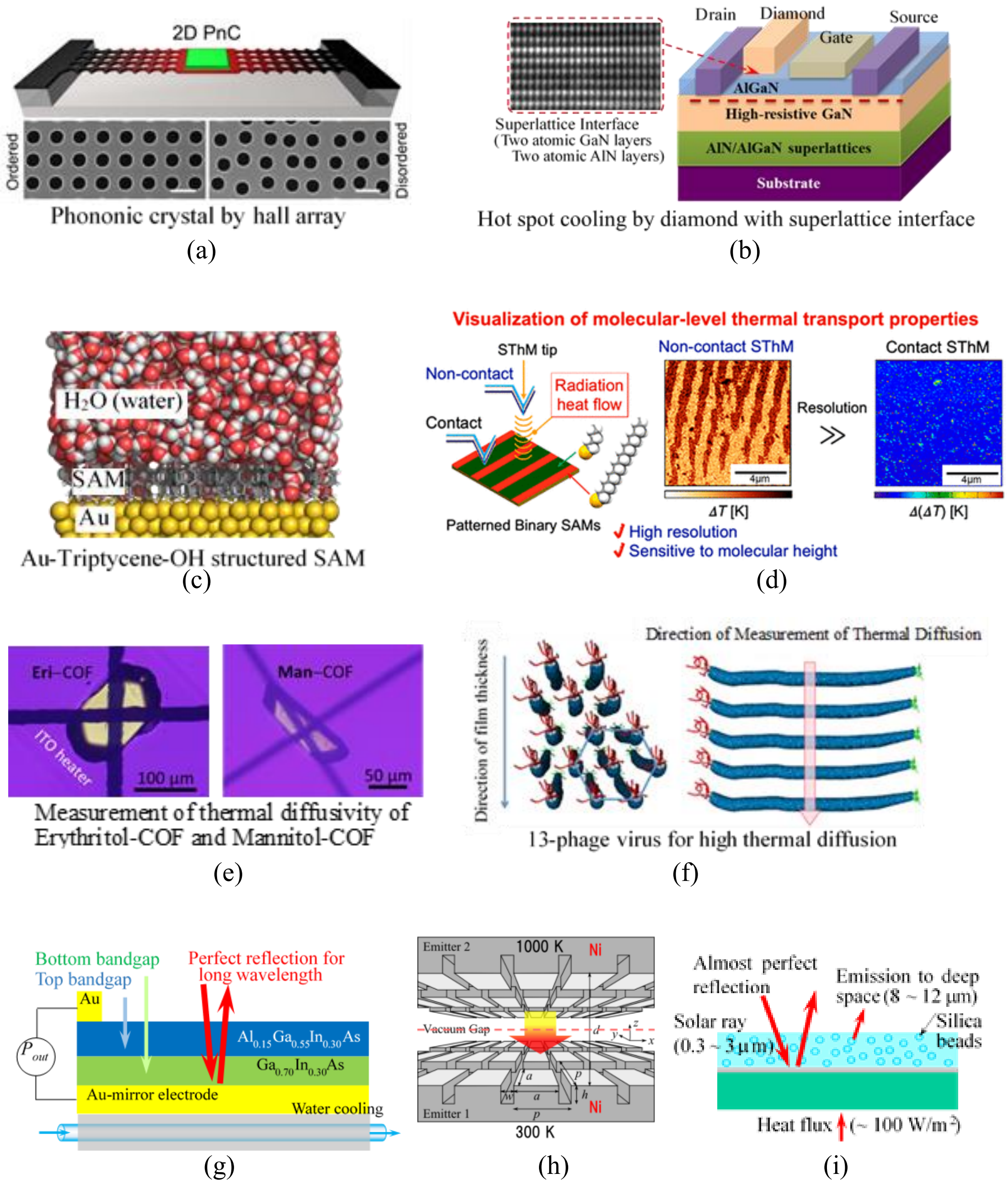

Fig.1 Various challenges to carbon neutrality from thermal engineering aspects