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| Title            | ナノ材料と流体チップの融合により微量赤外分析技術開発                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Sub Title        | Development of infrared analysis technology based on nanomaterials and fluid chips                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Author           | 牧, 英之(Maki, Hideyuki)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
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| Publication year | 2024                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Jtitle           | 学事振興資金研究成果実績報告書 (2023. )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| JaLC DOI         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Abstract         | <p>本研究では、前年度に引き続き、マイクロ流体などのマイクロデバイスを用いた分析技術に関する研究を進めた。これまでに開発したマイクロ高水圧アクチュエータにもとづき、ナノ流路開閉バルブの集積化と性能評価、流体操作の検証に取り組んだ。材料力学および流体力学による設計にもとづき、電子線リソグラフィ及びドライエッチング等のトップダウン加工によりガラス基板に幅160μm、深さ60nmのバルブを加工してナノ流路に接続し、マイクロ高水圧アクチュエータと統合した。また、1つのナノ流体デバイスにバルブ2個を構築することで、バルブの集積化を達成した。ナノ流路に試料を送液して開閉操作を行い、開閉率（バルブ閉時の体積 / バルブ開時の体積）6%、応答時間0.1秒、開閉操作1000回以上の耐久性を検証した。更に、バルブの開閉による流れのstop/go操作を検証し、分析等の応用に有効であることを示した。以上により、試料体積fL-pLの極限分析を可能とする試薬の輸送・切替といった複雑な操作を可能とするナノ流路開閉バルブの集積化に初めて成功した。また、ナノカーボン光源自体の開発と、それを用いた分析技術の構築を進めた。その結果、光源の開発では、高密度に配向したCNT配向膜を用いた結果、ダイレクトに偏光を発生させる新しい光源の開発に成功するとともに、この光源は、20MHz程度の高速変調性能を持つことが明らかとなった。さらに、シミュレーションによる解析を行うことで高速度変調性のメカニズムを解明したところ、カーボンナノチューブ配向膜の配向方向における高い熱伝導特性によることが明らかとなった。さらに、本研究では、ナノカーボン材料を用いた赤外分析チップ技術に関する研究を進めた。その結果、ナノカーボン光源を搭載したマイクロ流路デバイスの試作に成功し、実際に発光スペクトル等の取得に成功したことから、今後、分析実証を進める。</p> <p>Continuing on from the previous year, this study focused on analytical technology using microfluidics and other microdevices. Based on the micro high hydraulic actuator developed in the previous year, we integrated a nanofluidic valve, evaluated its performance, and verified its fluid operation. Based on the design by material mechanics and fluid mechanics, a 160 μm wide and 60 nm deep valve was fabricated on a glass substrate by top-down processing such as electron beam lithography and dry etching, connected to the nanofluidic channel, and integrated with the micro-high water pressure actuator. Integration of the valves was also achieved by constructing two valves in one nanofluidic device. The durability of the valve was verified by pumping a sample into the nanofluidic channel and performing open/close operations. The open/close ratio (volume when the valve is closed/volume when the valve is open) was 6%, response time was 0.1 second, and the durability of the valve was verified for more than 1,000 open/close operations. Furthermore, the stop/go operation of the flow by opening and closing the valve was verified and shown to be effective for applications such as analysis. As a result, we succeeded for the first time in integrating a nano flow open/close valve that enables complex operations such as transport and switching of reagents for extreme analysis of a sample volume of fL-pL. In addition, the development of the nanocarbon light source itself and the construction of analytical technology using it were promoted. As a result, in the development of the light source, we succeeded in developing a new light source that directly generates polarized light as a result of using a densely aligned CNT alignment film, and this light source was found to have a high-speed modulation performance of about 20 MHz. Furthermore, the mechanism of the high-speed modulation performance was clarified by simulation analysis, and it was found to be due to the high thermal conductivity in the alignment direction of the carbon nanotube alignment film. In this study, we also studied infrared analysis chip technology using nanocarbon materials. As a result, we succeeded in fabricating a prototype of a microfluidic device equipped with a nanocarbon light source and actually obtained emission spectra, etc. We will now proceed with analytical verification.</p> |
| Notes            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Genre            | Research Paper                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| URL              | <a href="https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=2023000013-20230021">https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=2023000013-20230021</a>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |



2023年度 学事振興資金（共同研究） 研究成果実績報告書

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| 研究代表者                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 所属 | 理工学部                                           | 職名     | 教授            | 補助額 | 1,200千円 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 氏名 | 牧 英之                                           | 氏名（英語） | Hideyuki Maki |     |         |
| 研究課題（日本語）                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |    |                                                |        |               |     |         |
| ナノ材料と流体チップの融合により微量赤外分析技術開発                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |    |                                                |        |               |     |         |
| 研究課題（英訳）                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |    |                                                |        |               |     |         |
| Development of Infrared Analysis Technology based on Nanomaterials and Fluid Chips                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |    |                                                |        |               |     |         |
| 研究組織                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |    |                                                |        |               |     |         |
| 氏 名 Name                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |    | 所属・学科・職名 Affiliation, department, and position |        |               |     |         |
| 牧 英之（Hieyuki Maki）                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |    | 理工学部・物理情報工学科・教授                                |        |               |     |         |
| 嘉副 裕（Yutaka Kazoe）                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |    | 理工学部・システムデザイン工学科・准教授                           |        |               |     |         |
| 1. 研究成果実績の概要                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |    |                                                |        |               |     |         |
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| 2. 研究成果実績の概要（英訳）                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |    |                                                |        |               |     |         |
| <p>Continuing on from the previous year, this study focused on analytical technology using microfluidics and other microdevices. Based on the micro high hydraulic actuator developed in the previous year, we integrated a nanofluidic valve, evaluated its performance, and verified its fluid operation. Based on the design by material mechanics and fluid mechanics, a 160 μm wide and 60 nm deep valve was fabricated on a glass substrate by top-down processing such as electron beam lithography and dry etching, connected to the nanofluidic channel, and integrated with the micro-high water pressure actuator. Integration of the valves was also achieved by constructing two valves in one nanofluidic device. The durability of the valve was verified by pumping a sample into the nanofluidic channel and performing open/close operations. The open/close ratio (volume when the valve is closed/volume when the valve is open) was 6%, response time was 0.1 second, and the durability of the valve was verified for more than 1,000 open/close operations. Furthermore, the stop/go operation of the flow by opening and closing the valve was verified and shown to be effective for applications such as analysis. As a result, we succeeded for the first time in integrating a nano flow open/close valve that enables complex operations such as transport and switching of reagents for extreme analysis of a sample volume of fL-pL. In addition, the development of the nanocarbon light source itself and the construction of analytical technology using it were promoted. As a result, in the development of the light source, we succeeded in developing a new light source that directly generates polarized light as a result of using a densely aligned CNT alignment film, and this light source was found to have a high-speed modulation performance of about 20 MHz. Furthermore, the mechanism of the high-speed modulation performance was clarified by simulation analysis, and it was found to be due to the high thermal conductivity in the alignment direction of the carbon nanotube alignment film. In this study, we also studied infrared analysis chip technology using nanocarbon materials. As a result, we succeeded in fabricating a prototype of a microfluidic device equipped with a nanocarbon light source and actually obtained emission spectra, etc. We will now proceed with analytical verification.</p> |    |                                                |        |               |     |         |
| 3. 本研究課題に関する発表                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                                                |        |               |     |         |

| 発表者氏名<br>(著者・講演者)                                                      | 発表課題名<br>(著書名・演題)                                                                                     | 発表学術誌名<br>(著書発行所・講演学会)                                                                              | 学術誌発行年月<br>(著書発行年月・講演年) |
|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|-------------------------|
| 俣野眞一郎, 小松夏実, S. Yu, J. Doumani, 志村惟, 河野淳一郎, 牧英之                        | カーボンナノチューブ配向膜を用いた変調黒体放射光源の開発 新規素材技術を活用した各種デバイスの開発                                                     | 第84回応用物理学会秋季学術講演会                                                                                   | 2023年9月                 |
| 湯本朋唯, 志村惟, 俣野眞一郎, 中川鉄馬, 牧英之                                            | 多層グラフェンを用いた赤外発光素子の特性評価                                                                                | 第84回応用物理学会秋季学術講演会                                                                                   | 2023年9月                 |
| Y. Shimura, . Nakagawa, S. Matano, H. Maki                             | Infrared Spectroscopy and Mapping Method Using Multilayer-Graphene Microemitters                      | THE INTERNATIONAL CONFERENCE on the SCIENCE & APPLICATIONS OF NANOTUBES                             | 2023年6月                 |
| S. Matano, N. Komatsu, S. Yu, J. Doumani, Y. Shimura, J. Kono, H. Maki | Thermal Radiation from an Electrically Modulated Aligned Carbon Nanotube Film                         | THE INTERNATIONAL CONFERENCE on the SCIENCE & APPLICATIONS OF NANOTUBES                             | 2023年6月                 |
| S. Matano, N. Komatsu, Y. Shimura, J. Kono and H. Maki                 | High-Speed Modulation of Polarized Thermal Radiation from an On-Chip Aligned Carbon Nanotube Film     | Nano Lett. 2023, 23, 21,                                                                            | 2023年10月                |
| Kensuke Mino, Yutaka Kazoe, Kyojiro Morikawa, Takehiko Kitamori        | Hydrophobic and oleophobic nanopillars reduce viscous drag in slit nanofluidic channels               | Applied Physics Letters, 123, 071602(6pp), (2023)                                                   | 2023年8月                 |
| Hiroki Sano, Yutaka Kazoe, Kyojiro Morikawa, Takehiko Kitamori         | Nanofluidic gas/liquid switching utilizing a nanochannel open/close valve based on glass deformation  | Journal of Micromechanics and Microengineering, 33, 085007(7pp), (2023)                             | 2023年7月                 |
| Rina Kakiuchi, Yutaka Kazoe                                            | Development of a sampling method for single nanoparticles utilizing hierarchical nanofluidic channels | The 16th IEEE International Conference on Nano/Molecular Medicine & Engineering (IEEE-NANOMED 2023) | 2023年12月                |
| Yo Saeki, Yutaka Kazoe                                                 | Measurement of particle behavior in micro/nanochannels using defocusing nano-PIV                      | The 76th Annual Meeting of the Division of Fluid Dynamics (2023 APS DFD), Washington, DC, U.S.A     | 2023年11月                |
| 杉田昌平, 小山瑞歩, 嘉副裕<br>杉田昌平, 小山瑞歩, 嘉副裕                                     | ガラスの弾性変形を用いたナノ流路開閉バルブの集積化に向けた水圧駆動アクチュエータの開発                                                           | 日本機械学会第14回マイクロ・ナノ工学シンポジウム                                                                           | 2023年11月                |