様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　元 年　 ６ 月 １１ 日現在

機関番号： １１３０１
研究種目： 若手研究(B)
研究期間： 2017～2018
課題番号： １７Ｋ１４０９５
研究課題名（和文） Micro/nano-machining using metal assisted chemical etching for micro/nano systems

研究課題名（英文） Micro/nano-machining using metal assisted chemical etching for micro/nano systems

研究代表者

グエン・ヴァン　トゥアン（Nguyen, Van Toan）

東北大学・マイクロシステム融合研究開発センター・特任助教

研究者番号：３０７９５１１７

交付決定額（研究期間全体）：（直接経費）　　3,300,000円

研究成果の概要（和文）：This research focuses on metal-assisted chemical etching method for micro/nano device fabrication. Not only high aspect ratio structures are targeted, but also micro/nano devices with specific applications are focused.

研究成果の学術的意義や社会的意義
The research results have been reported in the highlight journals as well as largest conferences in Micro/Nano field.

研究成果の概要（英文）：Research achievements can be summarized, as following: 1. High aspect ratio silicon structures produced via metal assisted chemical etching and assembly technology for cantilever fabrication. 2. Cantilever with high aspect ratio nano pillars on its surface for moisture detection in electronic products. 3. Ion transportation by gating voltage to nanopores produced via metal assisted chemical etching method. 4. Low cost and high-aspect ratio micro/nano device fabrication by using innovative metal-assisted chemical etching method.

研究分野： Micro/Nano devices

キーワード： Micro/Nano devices　Microfabication　Nanotechnology

１．研究開始当初の背景

Silicon, one of the most important materials in micro/nano systems, has been used for the fabrication of a wide range of micro/nano devices, including micro-fabricated resonators, power generators, bio/chemical sensors. Wet and dry etching techniques are typically employed for patterning silicon structures. The wet etching of silicon is performed in liquid phase in a special beaker placed in a fume hood. The commonly used wet etching solution are: KOH (Potassium hydroxide) and TMAH (Tetra-methyl ammonium hydroxide). The wet etching of silicon creates smooth etched surfaces; however, the aspect ratio structures of narrow trenches and nanowires are limited due to side etching. Currently, high aspect ratio of the etched structures is achieved by ICP-RIE (Inductively coupled plasma – Reactive ion etching) using well-established Bosch process. The Bosch process uses a combination of gases for etching and surface protection from further etching such as: SF_6 (etching cycle) and C_4F_8 (passivation cycle) gases. High aspect ratio silicon structures could be produced via Bosch process; however, rough etched surfaces (scallops) and defect generation on the etched silicon surface are its disadvantages. Moreover, most of dry etching methods require RF (radio frequency) generators, vacuum chambers, and precise mechanical parts that are expensive. This situation contributes to the device's fabrication cost that becomes high in the case of ICP-RIE microprocessing. Thus there is an urgent need, for novel fabrication methods for high aspect ratio silicon structures for micro/nano systems.

２．研究の目的

This research aims to create high aspect ratio structures as well as focusing on producing micro/nano devices with high performance. The research targets to fabricate humidity sensor for electronic devices, Knudsen pump, ion transportation, capacitive silicon resonators, and liquid thermoelectric power generator.

３．研究の方法

Many research groups are working on MACE technology due to its simplicity, low fabrication costs, and ability to generate good quality high aspect ratio of nano structures. MACE process is performed in a liquid or vapor phases, and enables the fabrication of anisotropic etched silicon structures at room temperature and atmospheric pressure. Proving ability of the fabrication of silicon nanostructures using MACE was demonstrated. Some papers mentioned MACE fabrication of nanostructures with applications in the field of energy conversion, storage and sensors, and bio-application and x-ray optics. Silicon nanowire fabrication by MACE was also presented in the literatures. Several papers report the MACE recipe for vertical etching, which applied for fabrication of the high aspect ratio nanowires. Patterning large size structures by MACE still face problems, because HF liquid cannot reach to center areas. Even that the oxide layer can be removed completely, the hydrogen gas (creating during MACE process) is still difficult to be released which could make the catalyst metal layer to float or buckle. In addition, when etching of patterns of different sizes is required, the etching rate is not uniform. Thus, the main problems of using MACE for micro/nano device's fabrication need to be addressed.

The novelty of the presented MACE process stands in the ability of fabrication of nano and micro structures in the same device. In this work we present the innovative MACE process that is based on a metal mesh used to create large patterning areas and also a combination of large and narrow pattering areas to produce device at micro/nano scale. Although many research groups are working on MACE method, based on our knowledge, this type of fabrication for micro/nano features in the same devices had not been achieved. Also in this work we present MEMS devices fabricated for the first time by MACE method such as; micro cantilever, capacitive silicon resonators and others. The novel method for patterning and also MEMS device fabrication and evaluation will be presented in this research.

４．研究成果

Our recent achievements related to MACE technology show the potential for forming high aspect ratio structures. Ultrahigh aspect trenches and pillars of 400 and 80, respectively, have been achieved. Silicon nanopillars with high density as well as high aspect ratio were demonstrated. We also conducted research for ion transport by gating voltage to silicon nanopores (15 nm-diameter and 200 µm-height) produced via MACE method. Cantilever and capacitive silicon resonators are successfully fabricated.

５．主な発表論文等

雑誌論文〕（計　　6 件）

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〔図書〕（計　１　件）

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〔産業財産権〕
○出願状況（計　　件）

名称：
発明者：
権利者：
種類：
番号：
出願年：
国内外の別：

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名称：
発明者：
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番号：
取得年：
国内外の別：

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ホームページ等

６．研究組織

(1)研究分担者
研究分担者氏名：

ローマ字氏名：

所属研究機関名：

部局名：

職名：助教
研究者番号（8 桁）：

(2)**研究協力者**
研究協力者氏名：
ローマ字氏名：

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