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Investigation of water distribution in proton exchange membrane fuel cells via Terahertz imaging

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ABSTRACT

Coherent transition radiation in a THz regime generated from a femtosecond electron bunch is explored for its potential use in imaging applications. Due to water sensitivity, the THz imaging experiment is performed on a proton exchange membrane fuel cell (PEMFC) to assess the ability to quantify water in the flow field of the cell. In this investigation, the PEMFC design and the experimental setup for the THz imaging is described. The results of the THz images in the flow field are also discussed.

1. Introduction

The proton exchange membrane fuel cell (PEMFC) is an electrochemical device being widely developed as an alternative source for clean energy. However, practical operation for the PEMFC has been greatly affected by its poor water management. Water is an essential part of the PEMFC. It is introduced to the cell through flow fields as a humidifier to reactants on both electrodes, and it is produced as a byproduct from the electrochemical reaction. Imbalanced water formation and removal can cause a state of drying or flooding in different areas within the cell [1]. Thus, it is important to be able to visualize and study the dynamic of water distribution in the PEMFC. Tools such as digital cameras, neutron imaging, and magnetic resonance imaging have been used for the *in situ* measurement of water in different parts of the PEMFC [2].

THz radiation, which lies between deep infrared and microwave, is known to be water sensitive. Strong attenuation by water content makes THz a promising tool for non-destructive inspection, such as in the food industry and in medical applications [3,4]. Our femtosecond electron source—developed at the Plasma and Beam Physics Research Facility, Chiang Mai University, Thailand—can generate a coherent transition radiation in the THz regime that ranges from 0.3 to 3 THz (10–100 cm^{-1}) [5]. Therefore, we aim to investigate the potential use of THz imaging for water distribution in the PEMFC. This paper focuses on water presence in the flow field of the PEMFC via reflective THz imaging. The preliminary results reported here indicate promise for the application of THz imaging to resolve water management problems in the PEMFC.

2. Materials and methods

2.1. PEMFC design for THz imaging

The flow field of the PEMFC is typically made of graphite, which is machined into a channel pattern that allows water and reactants to flow in and out. For a single cell, only one surface of the graphite is machined (called the dead-end flow field). Unfortunately, the dead-end flow field made of graphite is not transparent to the THz. In order to image the water in the flow field, we will need to machine through the channels and enclose with an appropriate window for THz probing. Our PEMFC design for THz imaging is shown in Fig. 1. As graphite is too brittle to machine through, we instead chose brass for our machine-through flow field. For the THz window, we have two candidates: one is a plexiglass window, and the other is a silicon window. Both window materials are transparent to a certain degree in the THz region. Silicon in particular has been reportedly used as a window in the reflective far infrared fourier transform spectroscopy of water [6]. In this work, we compare THz images obtained from the two materials prior to constructing the real cell with a more suitable THz window.

2.2. Reflective THz imaging setup

The schematic diagram of our reflective THz imaging setup is shown in Fig. 2. A parallel THz beam is reflected off a gold-coated

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