On the recyclability of used refrigerants using a mobile IR-device with IoT capabilities

Nikolaos Argirusis [1,], Georgia Sourkouni [2], and Christos Argirusis [3]*

[1] mat4nrg GmbH, 38678 Clausthal-Zellerfeld, Germany

[2] Clausthal Centre of Materials Technology (CZM), Clausthal University of Technology, 38678 Clausthal Zellerfeld, Germany

[3] School of Chemical Engineering, National Technical University of Athens (NTUA), 15773 Zografou-Athens, Greece

** nikos.argirusis@mat4nrg.de*

Introduction

Climate change is a serious problem caused primarily by the use of fossil fuels, although greenhouse gas (GHG) emissions are also regarded as a major contributor. Globally, greenhouse gas emissions cause an increase in average temperature, a decrease in ice mass, which causes sea level rise, and extreme climate events. Surface temperature has risen by 1.4 °C since the 1900s, with an exceptional increase of 0.18 °C predicted for June 2023 (Rohde 2023).

Fluorinated greenhouse gases (FGGs) are categorized as global pollutants. Most fluorinated greenhouse gases have an extremely high global warming potential (GWP) when compared to other greenhouse gases (Hansen et al., 2010). Historically, chlorofluorocarbons (CFCs) have been utilized as propellants for packaging materials, aerosol solvents, and refrigerants, and they have been identified as potential contributors to ozone depletion (Wallington et al., 1994). The Montreal Protocol of 1987 agreed to eliminate the use of CFCs. This led to the replacement of CFCs with hydrofluorocarbons (HFCs) (Sheraz et al., 2021). As a result of recent changes in environmental legislation, new refrigerant categories have evolved, with the goal of making refrigerant gases "greener" in terms of their impact on the ozone layer.

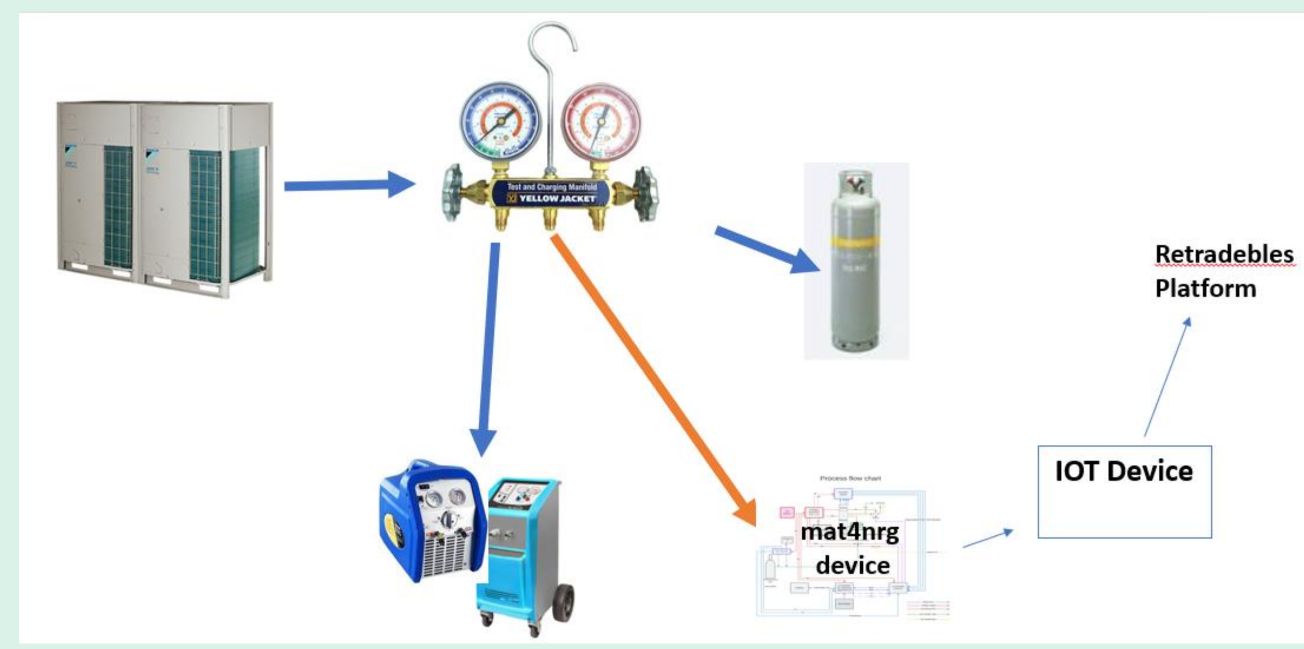

Figure 1: ReTradeables Process architecture

It is croucial to be able to detect the existence and concentration of these new gases, as well as older gases, in order to evaluate if the systems are operational and whether they can be recycled or destroyed. Additional reasons why quantitative measurements of the presence of such gases are required include: Leak detection during the manufacturing of air conditioning components to ensure that they are leak-free, as well as testing newer systems to ensure that they are running at maximum efficiency and mixing ratios.

Fast Fourier transform spectroscopy can be utilized for detection and quantification. However, this equipment is sensitive, heavy, and expensive, and they frequently require the assistance of a skilled technician while operating in the field. As a result, a mobile, user-friendly, and cost-effective detecting equipment would be beneficial.

In this paper, we report a detailed study on the classification of refrigerant gases in IoT-based gas detection systems. Through experimental assessments, we demonstrate the advantages of our approach in accurately discriminating between important refrigerant gases, including R32 and R134, with low latency. Data was collected using a range of widely available refrigerant gases. In this work, we use data from the refrigerants R32 and R134A. Therefore, thorough IR-spectra of the individual refrigerants are required. These were achieved utilizing an in-house 3D-printed tubular reactor with two BaF2 windows, which can be integrated into the beamline of a Bruker IR-Spectrometer. The data collecting process required exposing the IR-sensor to controlled gas environments containing refrigerant gases at various concentrations using precisely produced gas combinations.

Following the measurement, data are immediately sent to an IoT platform and made available to B2B clients.

Results

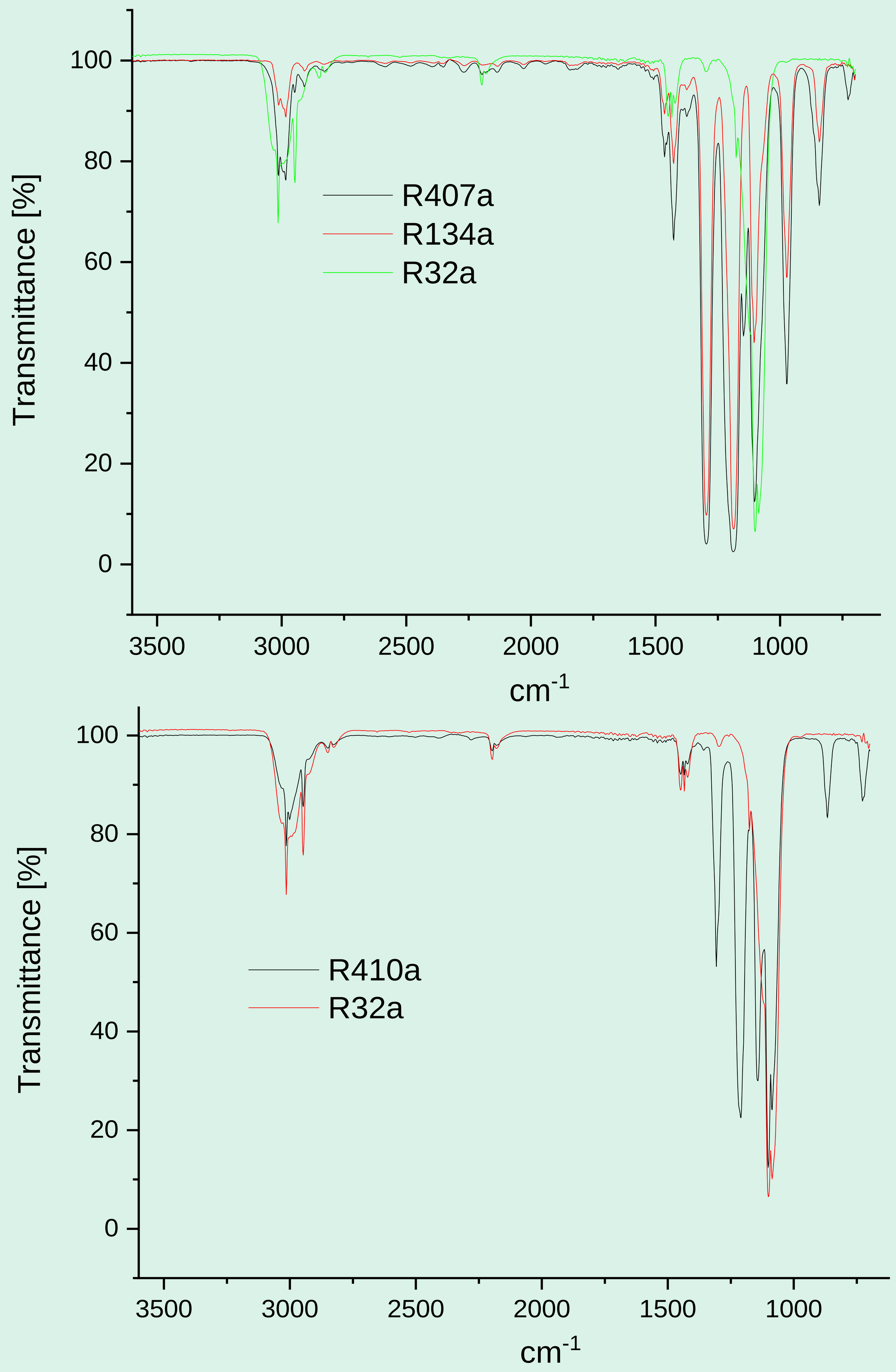

Figure 2: IR spectra of the refrigerants.

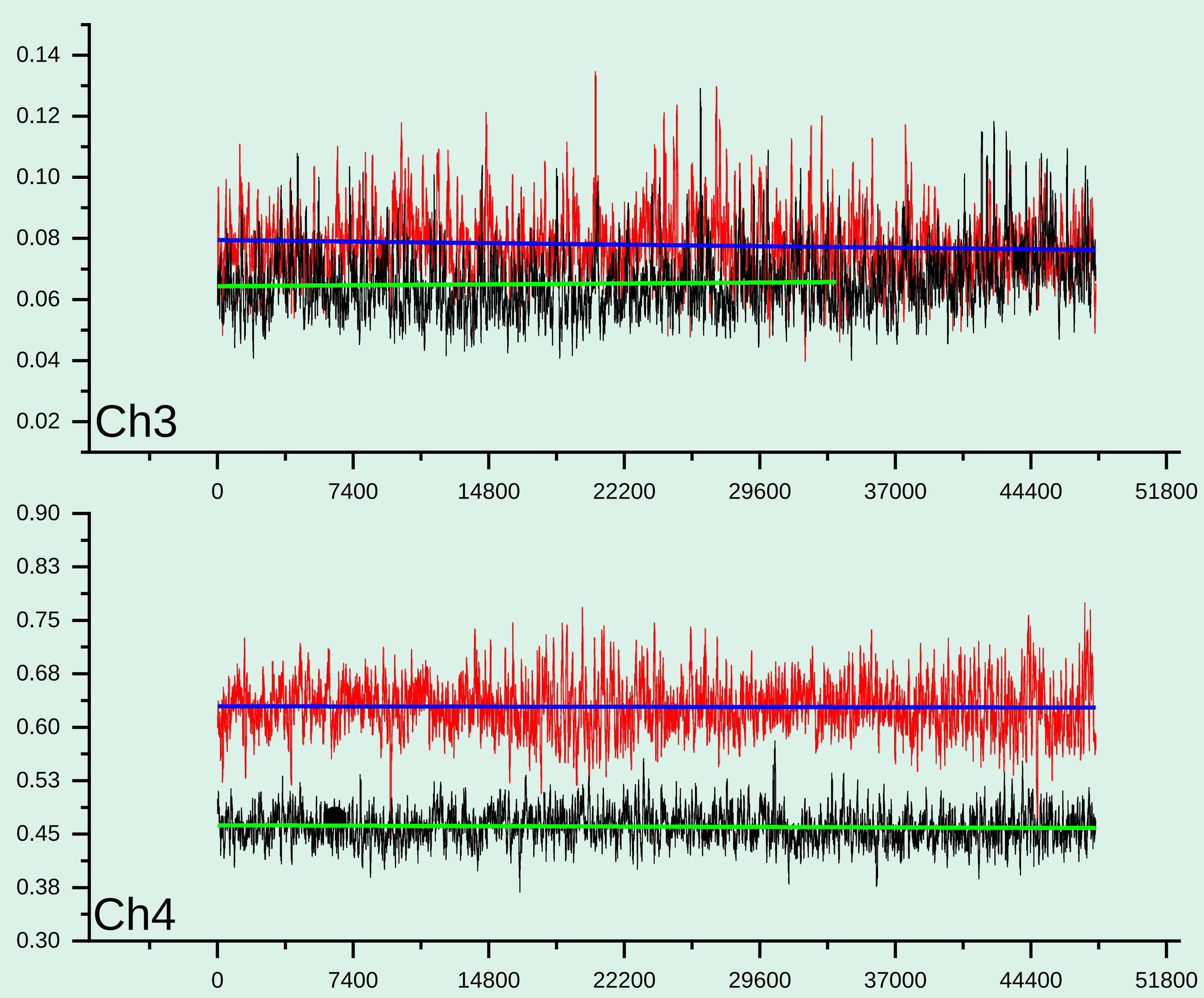

Figure 3: Measurement data using different wavelengths and determination of the gas as well as its concentration by normalizing the data using a reference signal .

Intensity according to Beer-Lambert-Low

The Extinktion E_λ (absorbance of the material for light with wavelength λ) is given by

$$E_\lambda = \log_{10}\left(\frac{I_0}{I_1}\right) = \varepsilon_\lambda \cdot c \cdot d$$

where

- I_0 : *Intensity of the source light* [$W \cdot m^{-2}$]
- I_1 : *Intensity of the transmitted light* [$W \cdot m^{-2}$]
- c : *Concentration of the absorbing substance* [$mol \cdot m^{-3}$]
- ε_λ : *extinction coefficient at the wavelength* λ.
- d : *thicknes of the sample (reactor length) [m].*

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Conclusions

An IR-sensor based portable device was developed, for the on-site refrigerants analysis, with IoT capabilities allowing the direct offer of the recycled refrigerant gas in a B2B platform.

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