

Interactive comment on “A centrifugal ice microtome for measurements of atmospheric CO₂ on air trapped in polar ice cores” by B. Bereiter et al.

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General comments:

This paper presents a novel dry extraction technique to free air from ice core samples using a Centrifugal Ice Microtome that shaves the ice into fine powder. Additionally, the analytical part of the measurement system is automated to a high degree and is equipped with a new detector for the analysis of CO₂ mixing ratios. The measurement principle is tested thoroughly on gas-free ice as well as on real ice of different type (bubble, BCTZ and clathrated) from different Antarctic ice cores.

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This paper is well suited for publication in AMT. It is well written, structured and convincingly presents the advantages of the new measurement system. Besides offering high gas extraction efficiency, the new system reduces contamination and improves precision and throughput of CO₂ mixing ratio measurements from ice cores. I recommend to accept the paper after minor revisions in relation to the comments below. My comments are mainly related to references and suggest the addition of extra information for the ease of the reader.

Specific comments:

Page 7868, line 26: The authors state that it took decades to reach a precision better than 5%. Can this be backed up by one or several references? A precision of $\pm 5\%$ seems to be high, since it corresponds to ± 14 ppm for preindustrial concentrations. Do the authors refer to reproducibility or accuracy rather than precision?

Page 7869, line 7: The reference (Anklin et al., 1995) focuses on CO₂ contamination due to the carbonate-acidity reaction. To also cover organic substances, I suggest the e.g. the reference (Tschumi and Stauffer, 2000), who focuses on both the carbonate-acid reaction and the oxidation of organic substances.

Page 7869, line 14: For the interested reader references should be added referring to e.g. CH₄ and N₂O measurements using a wet extraction technique.

Page 7869, line 28: I believe the extraction efficiencies from bubble and clathrate ice have been switched: The references given by the authors yield the following extraction efficiencies for bubble/clathrate ice: 62/52% (Schaefer et al., 2011); 75/54% (Sowers and Jubenville, 2000); 70/50% (Luethi et al, 2010); 80-90% (Ahn et al., 2009; clathrate extraction efficiency not explicitly stated but lower). Thus, “. . . release only 60%–90% and 50%–80% of the enclosed air in pure bubble ice and in pure clathrate ice, respectively. . .” would be correct.

Page 7870, line 16: The authors mention “our cracker system”. To introduce this sys-

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tem I suggest a phrasing like "the needle cracker system used previously at our lab". Later in the text the phrasing "our cracker system" is appropriate (e.g. on page 7871, line 12).

Page 7871, line 9 and page 7876, line 11: The diameter given in the reference (Uchida et al., 2011) is for clathrates only. Other enclosures like bubbles have different diameters. Thus, the sentence should be rephrased. E.g.: "The diameter of air enclosed as clathrates in polar ice...".

Page 7871, line 26 and page 7874, line 5: The authors write that the sample holder is rotated until the ice is consumed totally. How is this time determined? Is the sample consumption monitored somehow, e.g. by weighing the powder? Please specify.

Page 7873, lines 14-15: Are $\pm 0.02^\circ\text{C}$ and $\pm 0.1^\circ\text{C}$ the standard deviations (1σ) or maximum fluctuations (peak to peak)? Please specify.

Page 7873, lines 17-20: For the ease of the reader the authors could provide some references regarding the measurement techniques and sensitivities of the different optical spectrometers. Examples are (Baer et al, 2002) for the Los Gatos technique and (E. Crosson, 2008) for the Picarro technique. Something similar probably exists for the LI-COR principle.

Page 7874, lines 21-26: Could the authors be more specific about the pressure inside the sample cell of the LI-7000? Is this pressure identical to the pressure that is measured with the pressure gauge (determined by the amount of sample gas)? In other words: Is the LI-7000 actively controlling sample cell pressure or is this pressure determined by the sample size and the LI-7000 is passive?

Page 7874, lines 26-28: The authors use the raw data of the LI-7000 of both the sample and standard gas measurement to determine the CO_2 concentration in the sample. Thus, it seems the LI-7000 is used in a customized way. I think more explanation (1-2 sentences) on how the concentration is calculated would be helpful for the reader.

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Page 7875, lines 8-13: What was the reason to add the dry ice powder? Was it to keep the sample powder cool? Please specify. Also, I suggest to replace the wording "no optical difference" with "no visual difference" to make clear that no optical analysis of the powder took place.

Page 7876, line 20: Reference to Fig.9 is wrong. It should be Fig. 7.

Page 7879, line 7: The authors state here that direct expansion towards the measurement cell is the optimal case. However, on page 7874, line 18 it is said that 2.3 times more the amount of sample gas can be transferred to the measurement cell when the bellow is used in between. Reading this, I assumed that the bellow way is optimal. Is the bellow ideal only if the sample size is small or if the ice is fully clathrated? Please be more specific about that.

Page 7879, lines 17-20: Why have two different options been used? Does it take more time for the gas to expand from the CIM when BCTZ or clathrate ice is used? Please specify (this may be related to my comment above).

Page 7879, line 19: "Figs. 8 and 9" do not exist. I believe the authors refer to Figs. 6 and 7.

Page 7883, lines 4-5: The sentence "Due to this good reproducibility..." should be made specific for fully clathrated ice (and fully bubbly ice). E.g.: "...future measurement series on fully clathrated ice ...". Even though this sentence occurs in a paragraph where results from fully clathrated ice are discussed, it can be confusing since relatively large error bars (plus an offset) occur for BCTZ ice in the same figure (Fig. 6).

Page 7888, line 8: See comment above.

Figure 3: A grid in the background would help to read the portions easier.

Figure 6: In the figure caption it should be mentioned that "no error bars" correspond to a single measurement as the authors did in the caption of Fig. 7.

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Technical corrections:

Page 7689, line 1: remove "how"

Page 7869, line 4: "," missing after "(Kawamura et al., 2003)"

Page 7869, line 5: "," missing after "(Zumbrunn et al., 1982)"

Page 7871, line 5: remove "," after "LI-COR"

Page 7873, line 5: Unclear. Suggestion: replace ". At latter part of the CIM" with ", where".

Page 7874, line 24: replace "and" with ", which is"

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