



ONLINE-ANALYSIS OF TAR IN THE PRODUCT GAS OF THE BIOMASS GASIFICATION PROCESS VIA UV/VIS- SPECTROSCOPY

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INTRODUCTION

Biomass gasification is a very important technique in the production of renewable energy. Compared to solar or wind energy it allows a continuous production and usage of energy. Furthermore this technique provides various forms or sources of energy such as fuel and thermal or electrical energy[1]. Unfortunately the industrial exploitation of this technique is quite difficult due to technical barriers. The effectiveness of gasification plants mainly depends on tar formation. Tar is formed through the thermochemical conversion of biomass and represents a condensable side product that contains mostly aromatic or polycyclic aromatic compounds (PAH). Statements concerning the tar composition and concentration may help for a better understanding of the gasification process. Therefore the product gas is analyzed online via UV/VIS spectroscopy. For the evaluation of the obtained data the MCR (Multivariate Curve Resolution) is used. The combination of these methods and tools make it possible to characterize tars in the product gas stream during the gasification of biomass.

MEASUREMENT SETUP

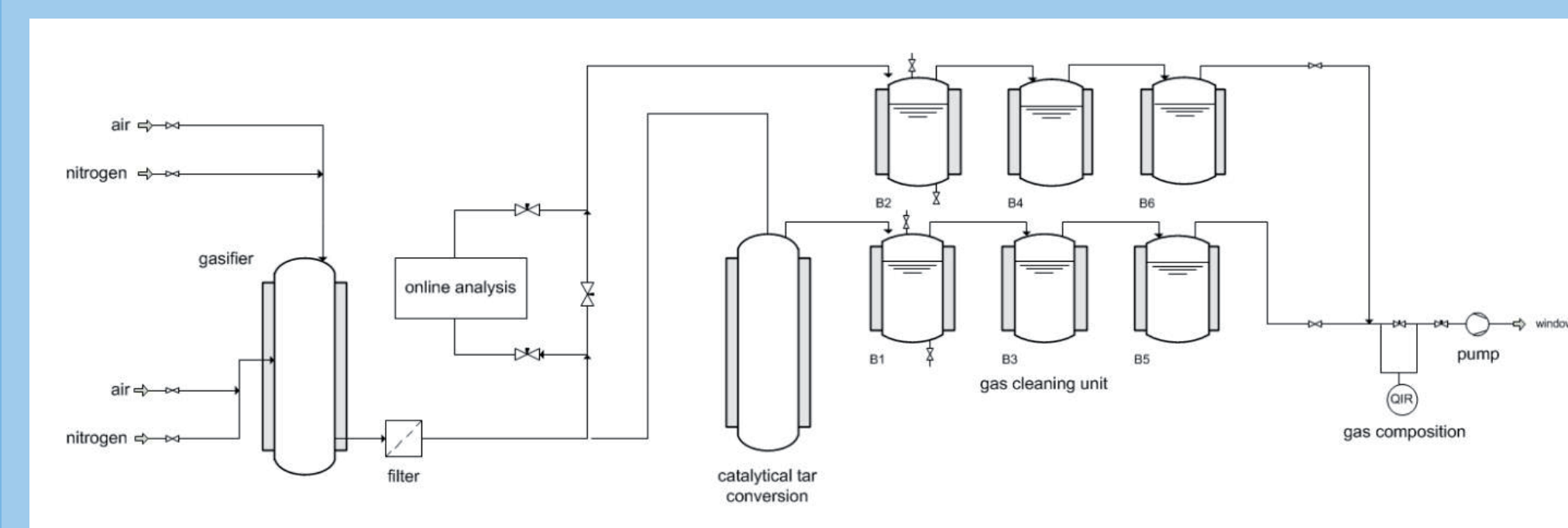


Figure 1. Schematic view of the experimental setup

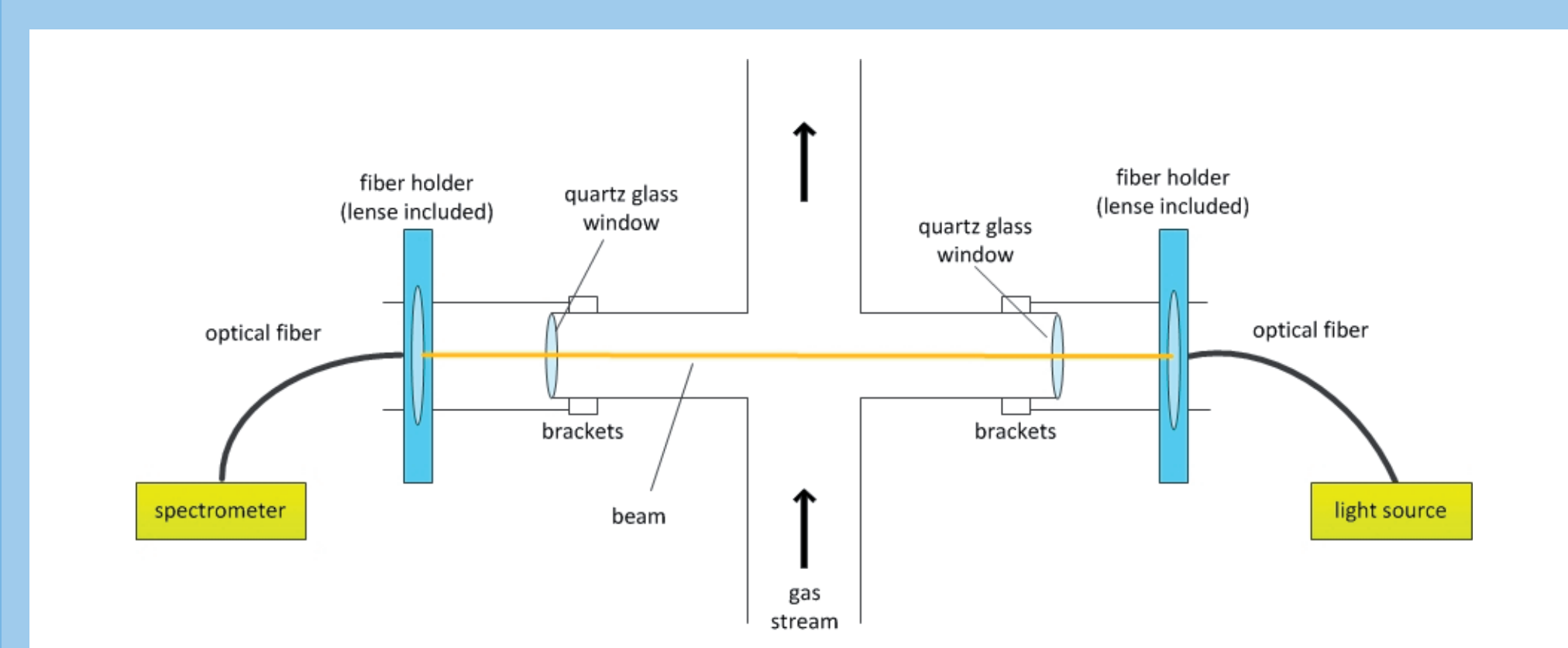


Figure 2. Schematic view of the measuring cell

EXPERIMENTAL

Online UV/Vis absorption spectra of the product gas acquired during the gasification of the wood/olive pellets. Online UV/Vis absorption spectra of the product gas acquired during the gasification of the wood/olive pellets.

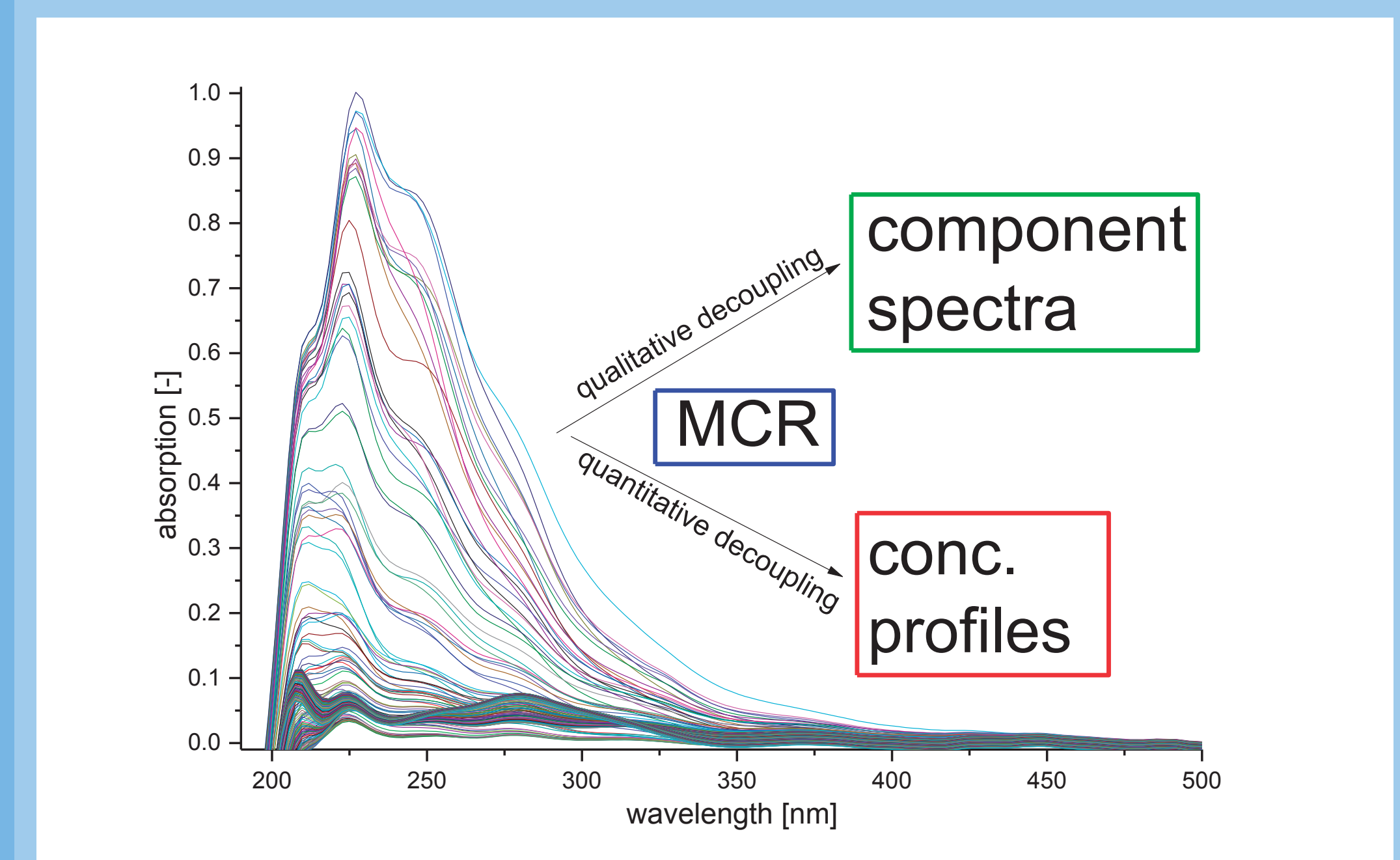


Figure 3. Absorption spectra of the biomass gasification process

RESULTS & DISCUSSION

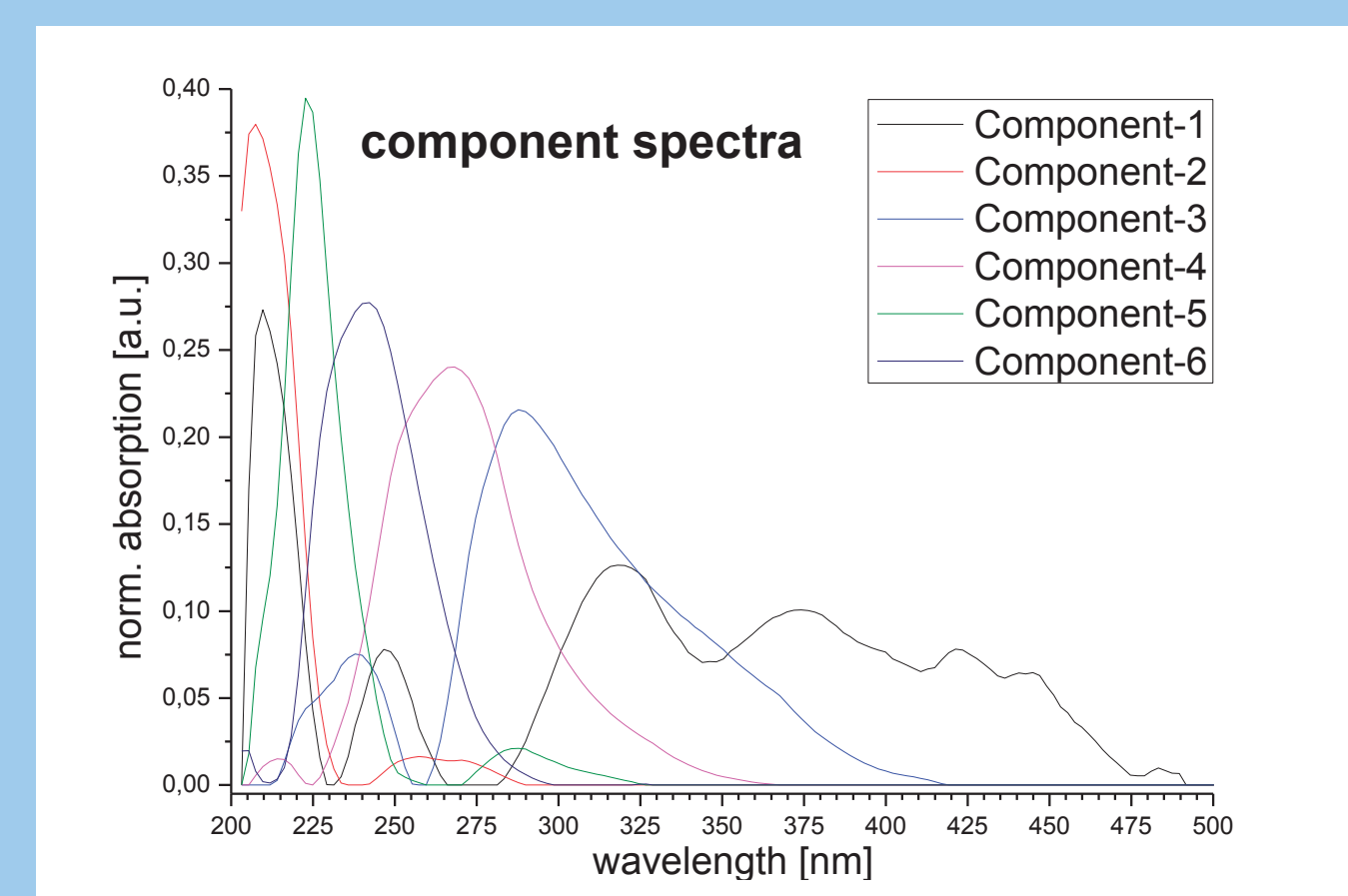


Figure 4. Decoupled component spectra of the absorption spectra

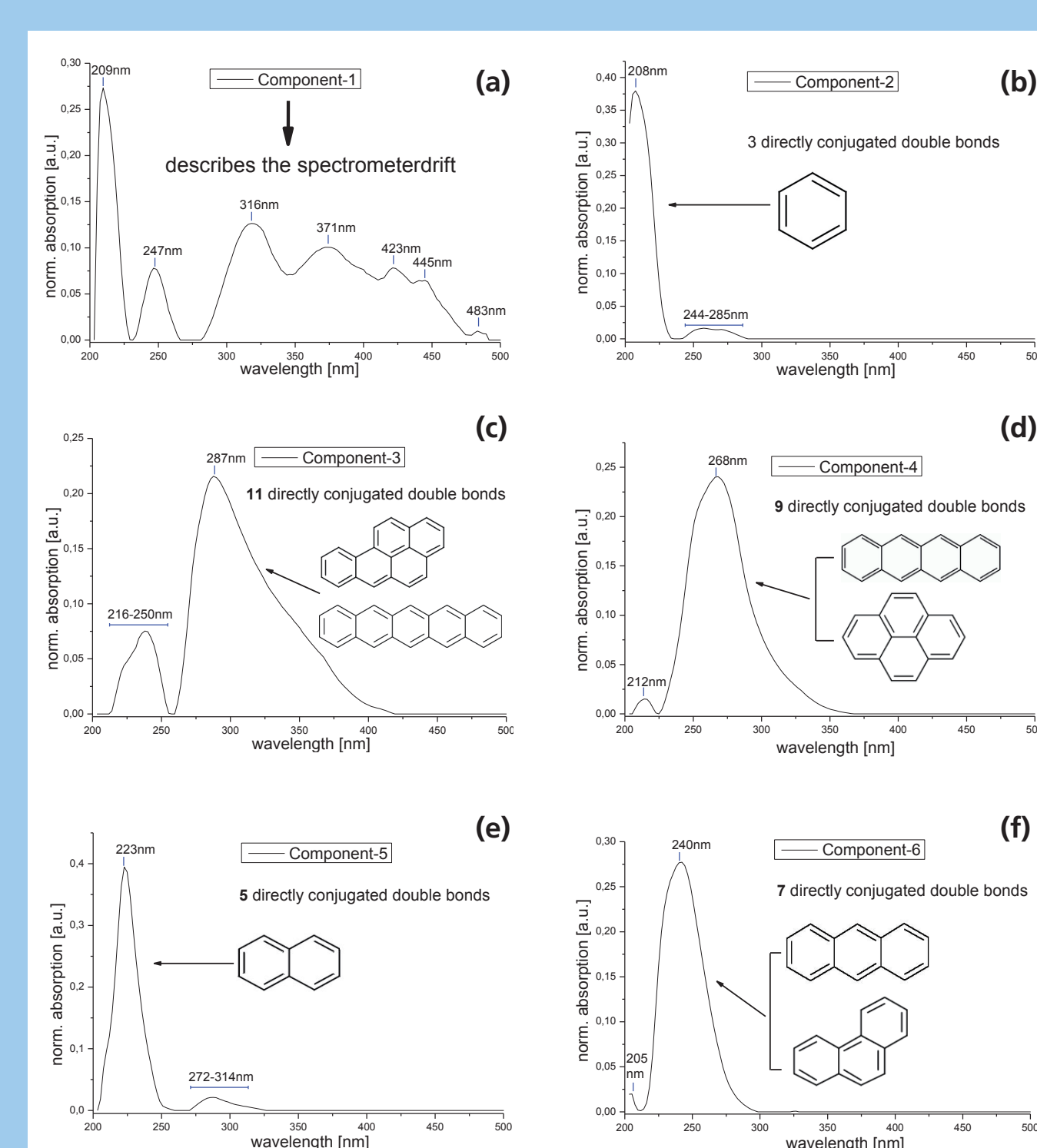


Figure 5. a) component 1, spectrometer drift ; b) component 2, 3 conjugated double bonds ; c) component 3, 11 conjugated double bonds ; d) component 4, 9 conjugated double bonds ; e) component 5, 5 conjugated double bonds ; f) component 6, 7 conjugated double bonds

Estimated spectra and estimated concentration were determined by the Multivariate Curve Resolution (MCR). Using the MCR, the spectra were decoupled in 6 components. The individual components describe spectroscopic information for a specific group of substances representing the similar absorption spectra.

Taking Table 1 into consideration, it is obvious that every substance group has a main peak in the same wavelength area. Furthermore every substance in a group has a common number of directly conjugated double bonds. Directly conjugated means that the double bonds are able to conjugate over the whole molecule.

The decoupling of the absorption spectra shows a suggestion of 6 components (Figure 4, Figure 5). As shown in Figure 5 a) the first component describes the spectrometer drift. Due to the fact, that MCR-Analysis is a combination of soft and hard

modeling, it is possible to recognize such circumstances [3]. In addition the other 5 estimated components match with the substance groupings listed in Table 1. Main and side peaks are equal in terms of wavelength and amount of the extinction coefficient with the result that component 2-6 can be assigned to tar substances as shown in Figure 5 b)-f). Furthermore the evaluation allows, under the consideration of individual exceptions (e.g. biphenyl, 1,1-binaphthyl), a decoupling into tars distinguished by 1, 2, 3, 4 and 5 aromatic rings.

Figure 6 shows the resolved concentration profiles. Concentration is plotted versus the spectra number. At this point it has to be mentioned, that the concentration is given in arbitrary units. Only the proportions of concentrations are meaningful. For a declaration e.g. in g/Nm³ the analyzing process has to be calibrated. However, the results are very relevant due to the fact that they yield component-oriented concentrations.

Table 1. Listing of different tars and their peaks with the corresponding extinction coefficient, sorted by the amount of the directly conjugated double bond [2].

substance	substance group	directly conjugated double bonds	aromatics with 6 Carbons	main peak [nm]	extinction coefficient	side peak [nm]	extinction coefficient
Fluorene	1	3	1	202	44000	255	19400
Toluene	3	1	208	7900	262	260	
Benzene	3	1	204	8800	254	250	
o-Xylol, m-Xylol	3	1	203	8900	256	260	
Indene	3	1	209	22000	252	9800	
Phenol	3	1	211	6000	271	2200	
o-Cresol	3	1	207	6000	272	2250	
Biphenyl	3	2	201	45500	247	17000	
Acenaphthylene	2	5	2	218	43700	312	16800
Naphthalene	5	2	211	49300	265	5600	
Acenaphthene	5	2	218	97000	275	6500	
Anthracene	5	4	220	101000	283	34000	
Phenanthrene	7	3	241	22000	210	11400	340 8500
Chrysen	9	4	267	139000	221	28500	
Naphthacene	9	4	269	41000	209	47500	
Benzo[a]anthracene	9	4	272	83000	209	50000	
Chrysen	9	4	278	83000	210	45200	330 29300
Fluorene	11	5	295	148000	323	8500	
Benzo[a]pyrene	11	5	296	129000	255	46000	216 35000
Dibenzof[ar]anthracene	11	5	280	133000	211	31000	326 8100
Dibenzof[anthracene]	11	5	290	129000	220	50000	251 30400
Benzo[ghi]perylene	11	5	286	68000	210	44000	320 11800

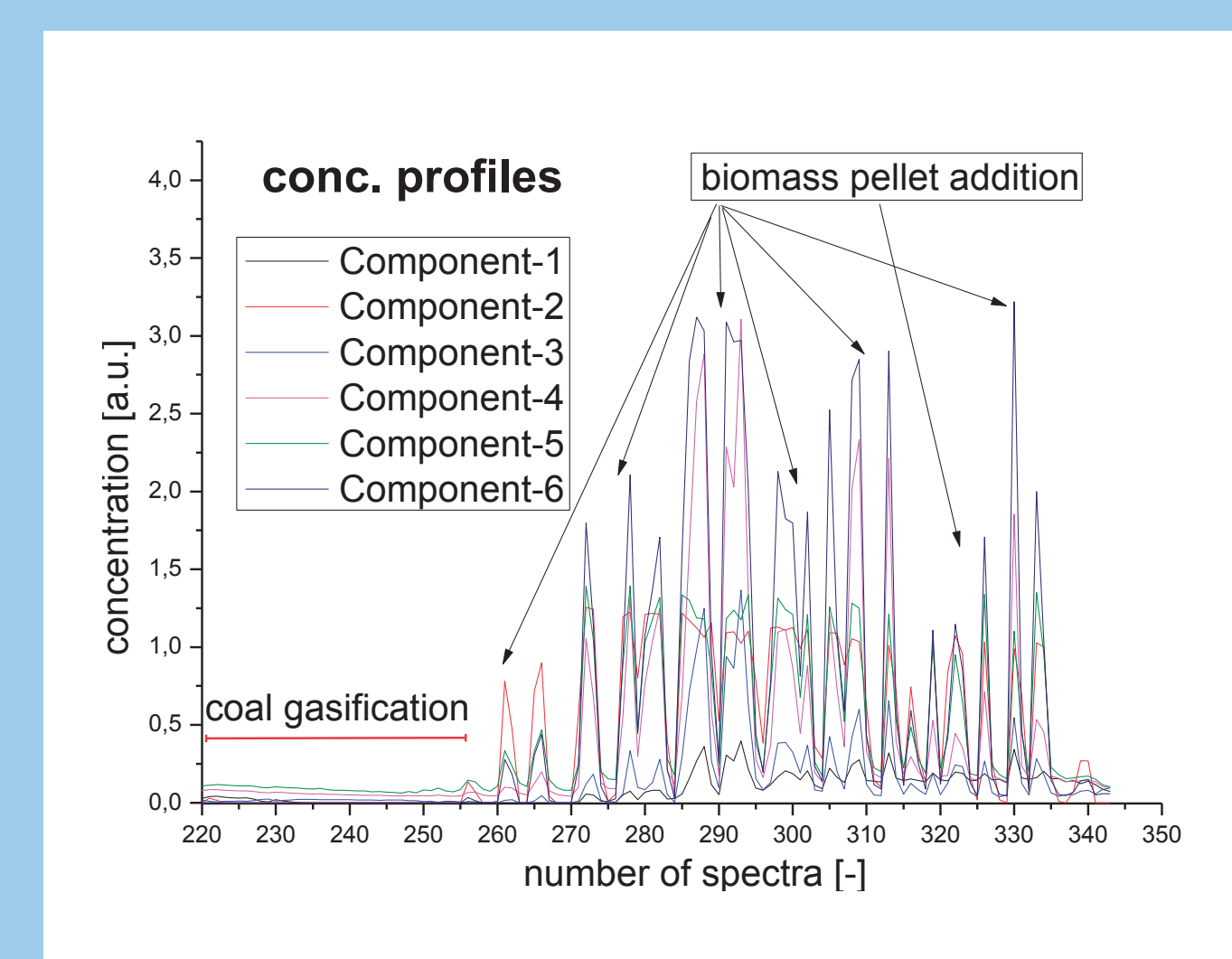


Figure 6. Estimated concentration profiles

CONCLUSION

The combination of UV/Vis spectroscopy and MCR method is used for the online characterization of tars in the product gas flow. It is shown that the absorption spectra of tars are characteristic for the amount of directly conjugated double bonds. Additionally, the decoupled absorption spectra show similarities to these findings. This is the reason why the qualitative analysis provides the result that the estimated components equal, with isolated exceptions, the number of aromatic compounds in the molecule. In addition to the qualitative analysis, it is also possible to make detailed statements on the concentration of every component, however only given in arbitrary units. To substantiate these statements for example in an amount of g/Nm³, the analyzing process has to be calibrated in the near future. Concerning the qualitative analysis, the influence of hydroxyl substituents has also to be examined in further research activity. Finally it is shown that combining UV/Vis-spectroscopy with MCR evaluation enables a detailed qualitative and quantitative analysis of tar which is easy to handle and cost-effective. This describes a major advance in the field of tar analysis.

ACKNOWLEDGMENTS

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LITERATURE

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