Investigation of polymerization of NVP and drying of PVP in an acoustic levitator using a smart camera for online process measurement

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Abstract

Spray processes are widely used in the chemical, pharmaceutical and food industries for the drying of products. The high surface to volume ratio of sprayed droplets allows high mass and heat flows under moderate conditions which predestines these processes for the treatment of sensitive substances. Furthermore the spray processes can be applied to reactive solutions where the synthesis and the drying of the product are combined. While the properties of the sprayed solution as well as the dried product are easily accessible via offline techniques the processes during the fall of the droplets are hard to measure. However these processes are important especially for the formation of the morphology of the dried particles. In order to investigate the occurrences during the drying process acoustic levitation can be employed for the contactless handling of droplets. Without the drawbacks of analyzing mass transfers on scales or on filaments the acoustic levitation is an ideal model system for falling droplets. Because of the fixed position of the droplet in the acoustic field droplets can be observed under conditions similar to those in a spray tower making the processes during the fall accessible to online analytics.

In this study the synthesis and drying of polyvinylpyrrolidone (PVP) in an acoustic levitator is investigated. The concentration of the monomer in the droplet is reduced by evaporation and polymerization. The competition between these partially parallel processes is monitored on the one hand by imaging to determine the loss of solvent and monomer due to evaporation and on the other hand by Raman spectroscopy to determine the consumption of monomer by polymerization. Combining Raman spectroscopy with principal component analysis demonstrated the feasibility of observing evaporation as well polymerization by Raman spectroscopy. This allows for investigation of both competing processes with the help of only one analytical method. In this context a smart camera system with integrated processing capabilities is introduced to compute droplet characteristics from the images online. The required algorithms were implemented in parallel on the field-programmable gate array (FPGA) of the smart camera to demonstrate the performance of smart camera systems in general. It was shown that the image processing algorithms for extracting relevant features of the objects can be implemented as single pass algorithms. With this kind of algorithms pixel data can be processed line-by-line in the same order the information is provided by the image sensor of the camera. Thus there is no need to store full images but only a single line. This is an important advantage when frame rates increase to several hundred frames per second or more as memory and bandwidth in most hardware architectures are limited. Since the pixel stream is processed in the camera and only relevant information is passed on to an external device, online measurements with high frame rates are achievable. This may be interesting for further applications in spray diagnostics.

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