Microreactors to produce explosive materials

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Microreactors can e.g. be used to produce explosive materials much more safely. Credit: Fraunhofer ICT

The larger the reaction vessel, the quicker products can be made – or so you might think. Microreactors show just how wrong that assumption is: in fact, they can be used to produce explosive materials – nitroglycerine, for instance – around ten times faster than in conventional vessels, and much more safely as well. At the ACHEMA trade fair, held June 18-22 in Frankfurt, researchers will demonstrate microreactors they use for a very broad range of chemical processes.

If the task is to tunnel through a mountain, workers turn to explosives: the 15-kilometer-long Gotthard Tunnel, for instance, was created by blasting through the rock with explosive gelatin made largely out of the nitroglycerine – better-known as dynamite. Producing these explosives calls for extreme caution. After all, no one wants a demonstration of explosive force in the lab. Because the production process generates heat, it must proceed slowly: drop for drop, the reagents are added to the agitating vessel that holds the initial substance. A mixture that heats up too suddenly can cause an explosion. The heat generated cannot be permitted to exceed the heat dissipated.

Researchers at the Fraunhofer Institute for Chemical Technology ICT in Pfinztal have developed a method for safer production of nitroglycerine: a microreactor process, tailored to this specific reaction. What makes the process safer are the tiny quantities involved. If the quantities are smaller, less heat is generated. And because the surface is very expansive compared to the volume involved, the system is very easy to cool. Another benefit: the tiny reactor produces the explosive material considerably faster than in agitating vessels. Unlike a large agitating vessel filled before the slow reaction proceeds, the microreactor works continuously: the base materials flow through tiny channels into the reaction chamber in “assembly-line fashion“. There, they react with one another for several seconds before flowing through other channels into a second microreactor for processing – meaning purification. This is because the interim product still contains impurities that need to be removed for safety reasons. Purification in the microreactor functions perfectly: the product produced meets pharmaceutical specifications and in a modified form can even be used in nitro capsules for patients with heart disease. “This marks the first use of microreactors in a process not only for synthesis of a material but also for its subsequent processing,“ observes Dr. Stefan Löbbecke, deputy division director at ICT. The microreactor process is already successfully in use in industry.

When developing a microreactor, researchers match the reactors to the reaction desired: how large may the channels be to ensure that the heat generated can be dissipated effectively? Where do researchers need to build impediments into the channels to ensure that the fluids are well blended and the reaction proceeds as planned? Another important parameter is the speed with which the liquids flow through the channels: on the one hand, they need enough time to react with one another, while on the other the reaction should come to an end as soon as the product is formed. Otherwise, the result might be too many unwanted by-products.

While microreactors suggest themselves for explosive materials, this is not the only conceivable application: researchers at ICT build reactors for every chemical reaction conceivable – and each is tailored to the particular reaction involved. Just one of numerous other examples is a microreactor that produces polymers for OLEDs. OLEDs are organic light-emitting diodes that are particularly common in displays and monitors. The polymers of which the OLEDs are made light up in colors. Still, when they are produced – synthesized – imperfections easily arise that rob the polymers of some of their luminosity. “Through precise process management, we are able to minimize the number of these imperfections,“ Löbbecke points out. To accomplish this, researchers first analyzed the reaction in minute detail: When do the polymers form? When do the imperfections arise? How fast does the process need to be? “As it turns out, many of the reaction protocol that people are familiar with from batch processes are unnecessary. Often, the base materials don‘t need to boil for hours at a time; in many cases all it takes is a few seconds,“ the researcher has found. Long periods spent boiling can cause the products to decompose or generate unwanted byproducts.

To develop and perfect a microreactor for a new reaction, the researchers study the ongoing reaction in real time – peering into the reactor itself, so to speak. Various analytical procedures are helpful in this regard: some, such as spectroscopic techniques, reveal which kinds of products are created in the reactor – and thus how researchers can systematically increase yields of the desired product, possibly even preventing by products from forming in the first place. Other analytical methods, such as calorimetry, provide scientists with information about the heat released over the course of a reaction. This measurement method tells them how quickly and completely the reaction is proceeding. It also provides an indication of how the process conditions need to be selected to ensure that the reaction proceeds safely. Researchers will be presenting a variety of microreactors, microreactor processes and process-analytical techniques at the ACHEMA trade fair from June 18-22 in Frankfurt.

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