Small stuff manufactured in big quantities

"There's a lot of research going on here into small-scale features, structures, and surfaces," says Dr Marcel Tichem, Associate Professor at TU Delft's department of Precision and Microsystems Engineering (PME), "but it all happens in science and we want to have an impact on society and industry. So we asked ourselves: how can we create value out of what is happening at the small-scale and what's being researched?"

"At PME, we're really multidisciplinary. All of us have some overlap with one or two colleagues but as a department, we're very diverse. So our first question was: how could we make more out of these individual disciplines?"

But PME also had a vision which is captured by the Nano Engineering Research Initiative or NERI - a platform for collaboration between academia and industry founded and powered by the department: "Our dream is to make positive use of phenomena at the small-scale, which is why we gave NERI the slogan 'Moving Nano from Lab to App' - and app in the sense of applying of research to society. So when we considered our future it all came down to two questions: how can we jointly create more synergy and address together bigger problems than you would be able to do as an individual? And how can we create sustainable relationships with other companies?"

From Sample-build to Repeatable Manufacturing

One aspect became clear straightaway; the necessity of being able to manufacture objects at the small-scale, a line of research that is Tichem's particular expertise: "You can only really benefit from the potential the small scale offers if you're able to produce devices in sufficient quantities and at acceptable cost levels and that's what I want to stand for. So if NERI is about moving nano from the lab to application, my own research is about moving manufacturing at the small-scale from sample-build to repeatable manufacturing."

This will involve speeding up the building process because currently, when research uncovers something new and promising, it is investigated and tested by building a sample, a process which may take a long time: "If we explore a new phenomenon, we build a sample which we research and characterize. And we measure wave-propagation, dynamic effects, thermal properties, and acoustic or optical properties, whatever the object is supposed to do, we investigate it and write a paper about it and that's the science bit! But the sample itself may have taken maybe a week, a month or even a year to manufacture, which is perhaps acceptable in the research context but totally unacceptable when moving towards the market and industry! So that's where we need to make a change."

Manufacturing Metamaterials

Tichem currently has two lines of research that are all about getting control over manufacturing at the small-scale so that it becomes repeatable or replicable. For example, Tichem is exploring the manufacture of metamaterials, structures made up of repeating unit cell designs that have been engineered so that they has properties they wouldn't normally have: "This structure for instance

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consists of individual units that are bi-stable, and are arranged to provide fascinating properties at the so-called meta-level. The surface connected to the metastructure can be bent, and will stay in that position."

The sample-build of this mechanical metamaterial was made using laser cutting and 3D printing, and was then assembled together. But Tichem's interest is in exploring how to manufacture this same metamaterial at a scale 10 or even 100 times smaller than the sample so that it still has all the same elements and the same if not even more refined dexterity: "So that's my ambition - that within five to ten years, I want to have established the technology, design rules and methodology behind the manufacture of such a material so that people can come and say 'I want to have this and that functionality' and then out comes the design and the way to produce it and a few moments later, it's been produced!"

Metamaterials with these kinds of properties could be used to make a mirror for beam steering, for example, as a lens on a satellite. Tichem: "All you need is the energy input and once it's there, it kind of stays there. We think that it is a competitive advantage if a lens is clamped into a fixture, which is not just a holding structure but has embedded functionality, so in a way, the material becomes the machine itself!" Such embedded functionality would lead to much more compact solutions for use in positioning systems and medical instrument, perhaps involving catheters that are 'steerable' within the human body. "So what we need to do now is develop processes that create materials at the small-scale length but also intrinsically at a high throughput. And one approach might be to make single layers and then stack them together, and exploiting replication processes, similar to a children's stamp, so that you make an entire structure in one step, rather than point-by-point adding of material as in 3D printing."

Nanoparticles as Biosensors

Another line of Tichem's research involves nanoparticles, which by virtue of their high surface-to-volume ratio have unique properties: "This makes them chemically very reactive so you could make a highly sensitive biosensor out of nanoparticle films. I want to be able to control where those nanoparticles are deposited, what the morphology and composition of the particle film should be, and I want to be able to do that locally so that I can print a microfluidic device with an embedded biosensor based on nanoparticles, which will act as a diagnostic instrument to be used in a hospital."