UCD Impact Case Study

Serendipity Swings Doors of Opportunity Open Wide for Nanobubble Generator Developers

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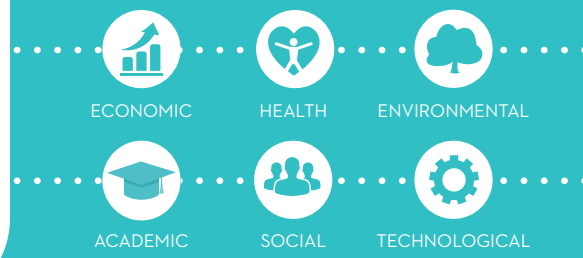

SUMMARY

The chance discovery of a novel, safe and cost effective way to generate within a liquid tiny bubbles of gas invisible to the naked eye (nanobubbles) by two alert and inquisitive researchers in the School of Chemical and Bioprocess Engineering has the potential to transform a panoply of industrial sectors worldwide. This discovery, made four years ago, has progressed to an advanced stage, with a spin out company established to support commercialisation of the patented new technology.

The easily controlled method to promote bulk-nanobubble formation has significant potential in strategically important industries worldwide, including the wastewater treatment, food/beverage production, chemical and (bio) pharmaceutical sectors. Other potential applications include irrigation, hydroponics, oil recovery, (bio-) gas separation and, perhaps most important of all, emissions control from carbon sources such as power plants and cement and steel production.

"This is a classic example, really, of the importance of researchers keeping an open mind. Our experiment was focussed on one thing, but when we identified an anomaly we ended up making a breakthrough in an entirely different area – and one with significant potential impact across a range of industries."

'The Most Exhilarating Moment of my Professional Life'

Dr Mohammad Reza Ghaani joined UCD in 2016 to study hydrogen storage in ice-like, crystalline solids known as gas hydrates. One day in early summer the following year he was engaged in an experiment to look at the effect of applying an electrical field (electrostriction) on hydrate growth in water. "After loading the system with gas I let it relax for half an hour. Before starting the experiment I noticed that the pressure in the system had gone down – but I couldn't find any leaks, so I discussed it with Niall." Professor Niall English remembers the moment vividly as one of instant inspiration. "Frankly, it was the most exhilarating moment of my professional life … I had a sudden vision of tiny bubbles on the nanoscale," he recalls.

Within minutes the two researchers were wondering about microscopic formation mechanisms for the then hypothetical bubbles and speculating on the many interesting possible industrial applications they might herald. Using a laser pointer Dr Ghaani was able to detect there was definitely something in the water, subsequently confirming them to be nanobubbles using a machine in the university's Chemistry Department. These are bubbles 70-120 nanometers in size – about 2,500 times smaller than a grain of salt.

This moment of serendipity brought the two researchers, and others who have since joined them, on a 2 -year adventure into such specialist areas as laser-light scattering, a powerful simulation tool called non-equilibrium molecular dynamics and the theory of microscopic electrostriction and polarisation, before eventually arriving at an understanding of exactly what was happening.

That team now includes the two co-inventors of the new technology. Dr Ghaani, who is developing it commercially, is also still supervising the research team active in the lab. Professor English, is now also CEO of spin-out company Aqua-B Ltd, established to commercialise the nanobubbles project. They have been joined by other researchers, who are exploring effective parameters on nanobubble generation and its stability for academic publications and who have been employed under commercialisation funding to scale up the nanobubble generator now being developed.

The evolution of nanobubble generators developed at different scales. It was all started from a simple electrode in a beaker and become a stand-alone industrial unit with 200 lit/min continuous generation capacity.

A Discovery that Keeps on Giving

The main paper on this significant discovery was published in Science Advances in April 2020. It indicated that nanobubbles could only be produced using an electric field in a high-pressure environment. But in the two years between that paper being submitted and published the researchers' knowledge had advanced and they knew it could be done at lower, even ambient pressure. This represents a huge advantage for practical applications, being both safer and requiring substantially less energy input, thereby reducing the cost of bulk nanobubble production.

The energy costs of this additive-free, non-contact method is of an order of magnitude many times higher than 'classical' approaches to nanobubble production. The nanobubbles produced using the new technology also have a far longer lifetime and are smaller and more uniform in size.

Professor English has a strong awareness of potential applications, Dr Ghaani says. As soon as the presence of long-lasting (metastic) nanobubbles in the treated water was demonstrated the team, and Professor English in particular, began coming up with new ideas for practical uses.

Key Areas of Opportunity

The early focus has been on wastewater treatment (WWT), a global market valued at over US$1 trillion. Because nanobubbles can remain stable in a liquid for days, unlike a few seconds for normal bubbles, they can introduce much larger quantities of stable dissolved oxygen into the water being treated to support microbial activity needed to treat the waste particles. It will dramatically cut energy consumption and costs in WWT plants, where a normal bubble aerator will account for as much as 55% of its total annual energy bill. Trials of AquaB's lightweight generator in the widely used "activated-sludge" approach to WWT have produced highly encouraging preliminary laboratory results. Because AquaB's patented way of making nanobubbles is also far more cost-effective than conventional alternatives it is a potential disruptor in the WWT industry worldwide, offering a promising range of social, environmental and economic benefits.

The team is also doing research into designs for deployment of solar-powered nanobubble generators positioned on artificial floating islands in lagoons and lakes. This will allow, for the first time, sustainable aeration of lake bottoms and sea beds in order to manage the growth of microscopic marine algae (phytoplankton) and algae within these waters. This can restore such water sources to living environments, with beneficial effects on water quality, plant and animal life. In less developed regions of the world, in particular, this can have a dramatic impact on agriculture, including restoration of fishing opportunities, enhancing economic opportunity and quality of life for communities living there.

"We were always thinking about adding extra oxygen to the water, for example in WWT, but one company contacted us from China asking about the possibility of creating nanobubbles for an electric shower; another, an oil company, asked whether our technology could address a particular problem it was experiencing," Dr Ghaani says.

"We have also established that we can create nanobubbles in liquids other than water and using a variety of gasses. Nor does it even have to be a gas; we have found we can create nanodroplets of one liquid within another, so we have ensured that our patents, filed with the help of NovaUCD, are deliberately broad to accommodate that."

Aqua-B has today won the 2020 IChemE Global Award in the Water category. This reflects strong international demand in our core nanobubble-generation technology, and big advances in nanobubble aeration for the activated-sludge process, as well as advances in DAF and ozone nanobubbles for disinfection.

"Frankly, it was the most exhilarating moment of my professional life ... I had a sudden vision of tiny bubbles on the nanoscale."

Having started the research using oxygen and air, the team has also found it effective in capturing CO_2 within water and for storing ozone, making it much more stable and transferable for a variety of applications. In other words, the possible applications for this novel production technique discovered by the team at UCD seem to be almost limitless. One of the frustrating challenges for the researchers when there is such a diversity of uses to which the technology can be put is the, perhaps understandable, requirement by funding agencies such as Enterprise Ireland that they focus their commercialisation efforts on a single application.

The two co-inventors were awarded Commercialisation Fund grants of €650,000 in 2019-2020 by Enterprise Ireland, with a special remit to support commercialisation of breakthrough scientific concepts developed within Irish third-level institutions. There have been expressions of interest from businesses in many countries, including the USA, Saudi Arabia & South Korea.

Research References

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M.R. Ghaani, P.G. Kusalik, N.J. English, Massive generation of metastable bulk nanobubbles in water by external electric fields, Science Advances 6 (2020) eaaz0094.

"A system, method and generator for generating nanobubbles or nanodroplets" PCT Application no. Application No:PCT/EP2019/078003

"A System and Method for the Treatment of Biogas and Wastewater" PCT Application No. PCT/EP2019/078017

"A system, generator and method for generating nanobubbles or nanodroplets and treating a multi-component mixture at ambient conditions PCT" Application No. PCT/EP2020/061107

Media and Social Media

Irish nanobubble breakthrough a possible game-changer for brewing industry

A new method to generate substantial volumes of nanobubbles in water

Researchers discover new method to generate nanobubbles in water

Acknowledgements

Enterprise Ireland Commercialisation Fund award registered 2019 for the project entitled 'Facile and reversible preparation of gas nano-bubbles for gas-in-liquid solubility enhancement'