Combating Cancer - Scaling Heights by Scaling Down

Suppose we are playing a combat game and we see an army attacking ours, wouldn't it be convenient if we could somehow sneak in some of our soldiers into the enemy camp and start fighting them from within? If the opponent army is actually a mass of cells multiplying without control, eating up important nutrients that we will otherwise use for our survival, it'll be called cancer. So by having soldiers who could fight this army from within, we'd have an advantage. This is exactly what Dr. Arivazhagan, a Post Doctoral Fellow of the Department of Metallurgical and Materials Engineering, is trying to achieve.

As we enter the Research Scholars Room at the Metal Forming Lab located beside the new Campus Cafe canteen, he greets us with an enthusiastic smile and there is an aura of confidence around him that portrays his proficiency in this field. His research involves making what are called nano-particles and infusing them with drugs to treat cancer. Cancer cells are targeted using these nano-particles so that the drug is delivered efficiently.

To understand more about the research, we must first understand what nano-particles really are. The word "nano" hints that it deals with particles at the nano-scale. The one foot scale we are better familiar with has divisions that go up to one millimetre, which is one thousandth of a metre. One thousandth of a millimetre is a micron. We're now on the scale of a human hair, which is about 40 to 50 microns wide. One thousandth of a micron is a nanometre. This is the nano-scale. It's difficult even to imagine such a small scale because we don't see particles of such a scale with our eyes. Large molecules and molecular clusters which make up many things around us belong to this scale.

Things get very interesting when we go to such small scales because by tweaking materials at this fundamental level, we get highly targeted and specific properties. Nano-materials have applications in many fields stretching from physics to biology and beyond. Medicinal applications exemplify the usefulness of nano-materials best because the bio-mechanisms that drive all living beings run on such scales. The applications of bio-nanomaterials are thereby vast.

Richard Feynman once said, "There's plenty of room at the bottom" while speaking about nanomaterials. The future looks pretty bright down here.

According to a report released by the International Agency for Research in Cancer which comes under the World Health Organisation, there were 14 million new cases of cancer in the year 2012, and the number is increasing. "There are about fifty types of cancer and lung cancer has the highest number of cases", says Dr. Arivazhagan, "Hence, I am working on finding a cure for it."

Common ways to treat cancer involve radiation, chemotherapy (extremely potent chemical drugs) and surgical removal of the tumour. Often two or more of these techniques are used at once. But there are other, more specific ways to treat cancer that can target only the cancer cells. In chemotherapy, the drug enters the bloodstream and affects all the cells that divide very quickly. Since cancer cells also exhibit this trait, they get destroyed. But there could be healthy cells that can be affected by the drugs. The cells in the hair roots and bone marrow for example divide more rapidly than many cancer cells. That is why this treatment leads to severe side effects, hair loss being the most benign of them. In targeted therapy, some properties of the cancer cells that are unique to them are used as criteria to select them for treatment. Hence, by employing nano-particles, we can have another medium of drug delivery which doesn't rely on the bloodstream entirely. It is possible to both coat and infuse nano-particles of the right size with drugs and deliver them to targeted cells. They should be small enough to not clog capillaries, but big enough to get imbibed into the cell. These particles are called nano-carriers and they have dimensions of about 50-100 nanometres. Due to its efficiency in drug delivery and fewer side effects, research on such drug delivery systems is very important for the future of cancer treatment.

In Dr. Arivazhagan's research, the nano-particles are made of Boron Nitride (BN), a ceramic. BN has attracted considerable attention as a nano-material because of its structural similarity to the more famous carbon nanomaterials. On one hand, BN is similar to diamond in its hardness and is used for sample cutting, but on the other hand, experiments suggest that it is a bio-compatible material. Dr. Arivazhagan explains the counter-intuitive properties. "It's a carrier", he says, "We need large surface areas for carriers and that doesn't depend upon a material's hardness". Depending on whether the drug is hydrophilic (water loving) or hydrophobic (water hating), we must design the nano-carriers by tuning the material at the nano-scale. We can make nanowires, nanotubes, and other 3D structures. In this research, spherical particles are being produced.

Figure 8: Dr. Arivazhagan with his Chemical Vapur Deposition (CVD) apparatus

The nano-particles are synthesised by a technique known as Chemical Vapour Deposition (CVD for short). We observe as he takes us around the lab, explaining the working of the CVD machine. From the name Chemical Vapour Deposition, it's understood that the required product is deposited from a vapour state. The product is formed from a reaction between a compound that easily evaporates and can produce the product by reacting with other gases. In the case of BN nano-particles, the volatile compound taken is Boron Trioxide and it's made to react with Ammonia. White BN nano-particles are deposited after the reaction. Liquid Ammonia and Boron Trioxide are first made into a mist using sound waves with frequency exceeding the human audible limit, in a machine called ultrasonic nebuliser. The mist is made to react at a temperature of around 1100 degrees inside a vacuum. "It takes about two and a half hours to reach that temperature and then the deposition takes place for thirty to forty minutes", Dr. Arivazhagan says enthusiastically. After leaving sufficient time for the sample to get deposited, the vacuum is turned off and the sample is collected. The size is controlled by changing the conditions of the reaction. "We need a lot of sample to perform the analysis because there is an amount of trial and error involved in the analysis stages" he comments. The collection of the sample is being carried out presently, the next step is analysing the properties of the obtained nano-particles in a series of steps called characterisation.

Once the BN nano-particles are found to be ready, experiments will be conducted with curcumin as the cancer therapy drug. Curcumin, a component of turmeric, is a natural cancer treatment drug often used for lung cancer therapy. The experiments involve analysis of four sets of sample lung cancer cells — one set without any added drug or delivery system, one set of cells treated with curcumin alone, one set with cells treated with BN nano-particles not infused with curcumin, and one set of cells treated with BN nano-particles infused with curcumin. From the results of these analyses, which includes the measurement of cytotoxicity or the ability to kill cancer cells, it'll be known if such a drug delivery system is viable or not. "I chose curcumin because it's cheap", Dr.Arivazhagan observes, "Since it's difficult to manufacture nano-particles, it's important that the other components are less expensive so the treatment can be made affordable."

Nanomaterials is a truly interdisciplinary field with a combination of Physics, Chemistry, Biology, Materials and Engineering involved and the future looks promising as the conventional boundaries are dissolving in the field. As far as biological applications go, this is the right moment for a revolution and we are part of one now. "If the results are good, we can even patent it", Dr.Arivazhagan remarks with a smile. Success of this research will mean there's a possible and accessible treatment available for lung cancer in the future, and that is his dream. We hope that his dream comes true.

Prof. S S Bhattacharya is a professor in the Department of Metallurgical and Materials Engineering. He did his undergraduate and doctoral studies in the same department. His research interests are Nanocrystalline Materials, Superplasticity of Materials (Analytical and Experimental), Superplastic Forming, Metal Forming, High Temperature Deformation Behaviour of Materials, and Advanced Materials Testing. You can know more about his research at https://mme.iitm.ac.in/ssb/

Meet the Author

R Mythreyi is a second year undergraduate student of the Department of Metallurgical and Materials Engineering. Having got a glimpse of the world of materials science,she plans to pursue research in the field. Her compelling love for books and music tends to make her reading list and playlists surpass the borders of conventional genres. She also has a keen interest in exploring ways to optimise the use of technology. Oftentimes, she finds solace in writing.