Light-Activated Nanobots for Targeted Breast Cancer Therapy

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Scientists from the **Institute of Nano Science and Technology (INST), Mohali**, and the **Bhabha Atomic Research Centre (BARC), Mumbai**, have developed tiny **light-activated nanobots** that could help target breast cancer cells more precisely. The research was led by **Dr Jiban Jyoti Panda (INST)** and **Dr Santosh K. Gupta (BARC)**, with **Swapnil Srivastava** as the first author, and was published in *ACS Applied Materials & Interfaces*.

About Light-Activated Nanobots for Targeted Breast Cancer Therapy

Light-activated nanobots are tiny therapeutic particles that can be directed using light and can help deliver cancer treatment closer to breast cancer cells.

- **What makes them different**: Ordinary nanoparticles mainly carry a drug and rely on natural processes to reach the tumour, whereas these nanobots can be guided towards a desired area using near-infrared (NIR) light.

- **How they respond to light**: The nanobots are made using upconversion nanoparticles (UCNPs) that respond to NIR light and help the nanobots move towards the light source.
- **Why this matters**: This gives researchers greater control over where the nanobots move and where the treatment is activated, which can support more targeted breast cancer therapy.
- **Fuel-free movement**: Unlike some nanorobots that need a chemical fuel to move, these nanobots use energy from externally applied NIR light to generate the heat and movement needed for their motion.

Why are Light-Activated Nanobots Needed for Targeted Breast Cancer Therapy?

The main aim is to make breast cancer treatment more targeted, so that the therapy acts more strongly on cancer cells while limiting its effect on healthy tissues.

- **Problem with chemotherapy**: Conventional chemotherapy circulates through the body, so the medicines can affect healthy cells as well as cancer cells, causing side effects.
- **Problem with passive nanomedicine**: Many nanoparticle-based treatments depend on the nanoparticles naturally reaching and accumulating in the tumour, giving limited control over their movement and precise localisation.

Light-activated nanobots for targeted breast cancer therapy can be guided using NIR light and can recognise specific cancer cells, offering greater control over where the treatment acts.

How Do Light-Activated Nanobots Work?

The nanobots combine three functions-movement, targeting and cancer-cell destruction.

- **Step 1 – Movement**: When a 980-nanometre NIR laser is applied, the nanobots absorb the light and produce heat. This creates a temperature difference that makes them move towards the light source. This light-directed movement is called phototaxis.
- **Step 2 – Cancer-cell recognition**: The surface of the nanobots is modified with folic acid. Breast cancer cells with high levels of folate receptors can recognise and interact with the folic acid on the nanobots.
- **Step 3 – Cancer-cell destruction**: The NIR light produces heat that damages cancer cells. This is called photothermal therapy (PTT).
- **Step 4 – Additional damage**: The nanobots also contain the photosensitiser rose bengal. When activated by light, it helps produce Reactive Oxygen Species (ROS), which damage cancer cells. This process is called photodynamic therapy (PDT).
- **Step 5 – Combined action**: Heat and ROS attack cancer cells through different mechanisms, producing a stronger therapeutic effect than either treatment alone in the study.

What Did the Researchers Find?

The researchers tested the light-activated nanobots for targeted breast cancer therapy in laboratory cell models and in mice carrying breast tumours.

The nanobots showed therapeutic activity against breast cancer cells. In the mouse model, treatment activated by NIR light led to reduced tumour growth. The combination of photothermal and photodynamic effects produced a stronger tumour-inhibiting effect than either approach used separately.

These findings show the potential of the technology, but they do not yet establish it as a treatment for human patients.

Light-Activated Nanobots Significance

Light-activated nanobots can make cancer treatment more precise and controlled by combining light-guided movement, cancer-cell recognition and localised therapy in one system. This may help reduce damage to healthy tissues, improve the effectiveness of treatment and advance precision medicine in cancer care.

Light-Activated Nanobots Limitations

Light-activated nanobots for targeted breast cancer therapy are still at the preclinical stage. Their use in humans may be limited by poor NIR-light penetration into deep tumours, difficulty in controlling nanobots inside the body, and the need to establish their long-term safety and toxicity through further studies and clinical trials.

Further preclinical studies and human clinical trials are needed to establish the safety and effectiveness of light-activated nanobots, along with improvements in NIR-light delivery and precise control of nanobots inside the human body, before their wider clinical use.
