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Tentative topic of the invited talk

Microfluidic synthesis of cadmium-free quantum dots for cancer imaging: prototype and market insights

Abstract of the invited talk

Malignant tumors continue to rank among the leading causes of death worldwide, accounting for a major portion of global disease burden. Early and accurate detection of cancer remains critical for effective treatment, yet current diagnostic imaging techniques still face limitations in sensitivity, spatial resolution, and reproducibility. Ultrasound imaging has gained widespread clinical use due to its real-time capability, noninvasiveness, and cost-effectiveness, allowing dynamic observation of tissue structures through acoustic impedance differences. However, the intrinsic contrast of ultrasound is often insufficient to precisely identify small or early-stage lesions, emphasizing the urgent need for advanced and biocompatible imaging contrast agents.

Indium phosphide (InP) thick-shell quantum dots (QDs) have recently emerged as an attractive class of nanomaterials owing to their low toxicity, high photostability, tunable emission spectra, and strong luminescence. Compared with traditional cadmium-based QDs, InP QDs offer improved biocompatibility and environmental safety, making them more suitable for biomedical applications. When incorporated into ultrasound-responsive nanobubbles, these QDs can serve as dual-modality probes, enhancing both optical and acoustic contrast. This dual functionality holds great promise for precise cancer imaging and real-time monitoring of disease progression. Nevertheless, conventional one-pot synthesis methods for InP QDs are complex, highly sensitive to temperature and precursor ratios, and often yield inconsistent particle sizes, leading to poor reproducibility and limited scalability.

This research work aims to develop an integrated microfluidic synthesis system for the continuous and controllable production of cadmium-free InP thick-shell QDs optimized for cancer imaging. The proposed system will employ precisely regulated flow dynamics, temperature gradients, and mixing conditions to ensure uniform nucleation and growth of QDs. Through this approach, we expect to achieve high reproducibility, narrow size distribution, and consistent optical performance. Additionally, a high-throughput microreactor chip will be designed to provide production efficiency comparable to large-scale batch synthesis, enhancing industrial feasibility.

The anticipated outcomes of this work include:

1. A microfluidic platform that overcomes the limitations of conventional one-pot synthesis by improving control, reproducibility, and scalability.

2. The establishment of a strategic technological foundation for Taiwan to innovate in diagnostic imaging materials and reduce dependence on imported medical technologies.
3. Long-term advancement of Taiwan's R&D capabilities in nanomaterial synthesis, optoelectronic devices, and biomedical engineering, fostering cross-disciplinary innovation and industrial competitiveness.

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