Printing beyond barriers: A pathway to non-invasive deep inside body printing

Mohsen Habibi, Assistant Professor of Mechanical and Aerospace Engineering, UC Davis**, Aijun Wang**, Professor of Surgery and Biomedical Engineering, UC Davis, **James Marcin**, Professor of Pediatrics, UC Davis.

Background: The concept of non-invasively implanting biocompatible structures within the human body using 3D printing technology and injectable materials was introduced over two decades ago. This innovation held the potential to revolutionize procedures that traditionally required invasive surgery. However, existing bioprinting methods have been limited by their reliance on light-based energy sources, rendering them unsuitable for deep-tissue applications within the human body. Light cannot effectively penetrate opaque biological tissues (Fig.1). Direct Sound Printing (DSP) [1]–[5], introduced by Dr. Habibi as a novel additive manufacturing technology circumvents these limitations. DSP harnesses ultrasound, capable of penetrating deep into biological tissues with pinpoint accuracy. This breakthrough introduces Remote Distance Printing (RDP) [1], [6] paradigm, enabling printing at otherwise inaccessible locations without requiring direct access to the printing site.

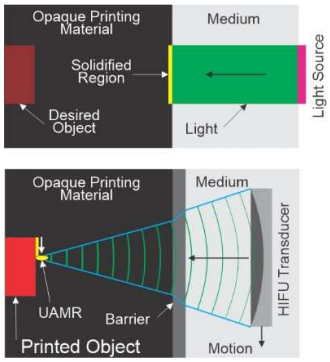

Fig.1. Penetration Comparison between light based 3D printing methods (top) and sound based method (bottom) [1].

Idea: Despite recent significant developments in Additive Manufacturing (AM) technologies, from printing materials to processes, light and heat are still the only energy sources used in AM to drive chemical reactions or physical transformations. Therefore, materials in AM processes are limited to photosensitive resins and thermoplastic filaments or powders. Parameters controlling the chemical interactions [7] are defined by the amount of energy per molecule, interaction time and pressure which are the control parameters in the islands of chemistry (Fig. 2). Conventional AM energy sources, light and heat, do not utilize the maximum potential of the chemistry in terms of the control parameters. DSP *via* Sonochemistry pushes these parameters to their limits which introduces an innovative route for printing specifically biopolymers. One of the applications of paradigm of DSP-RDP is bioprinting inside body (Fig. 3). The biomaterial is injected to the target region and the ultrasound source is spatially manipulated to print the desired geometry. The desired object could be an implant or scaffold with or without embedded cells or drugs eliminating the need for invasive surgeries.

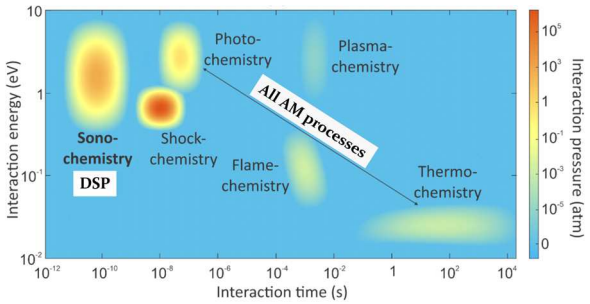

Fig.2. Islands of chemistry (inspired by [5]), compassion between all AM processes and Direct Sound Printing (DSP).

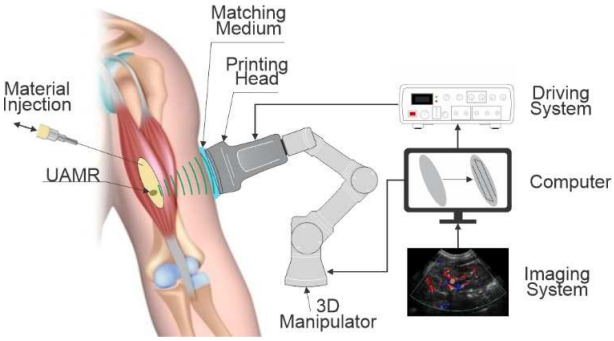

Fig.3. Schematic of remote distance printing using DSP method through integration with an imaging system [1].

Significance: Current practices of implanting acellular and cellular constructs through invasive surgical procedures intrinsically have associated risks for patients. These risks include: 1) Failure of wound healing at the surgical site, potentially leading to complications such as seroma (fluid accumulation), hematoma (blood clot), wound dehiscence (wound opening), or hernia, 2) Risk of infections due to the invasive nature of the procedure, which can introduce pathogens into the body, 3) Potential nerve injuries, which can occur during surgery and may lead to sensory or motor deficits in the affected area, 4) Damage to peripheral tissues surrounding the operated site, which can result from the surgical manipulation and may lead to additional complications or prolonged recovery and 5) Risks associated with general anesthesia. Profs. Wang and Marcin from UC Davis Health are well positioned to collaborate with Dr. Habibi for reduction to practice of DSP-RDP and bring this exciting platform technology to meaningful medical and surgical applications.

References:

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