INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

Metal-based micro-manufacturing involves fabricating miniature components using micro-tools while maintaining tolerances to only a few microns. This precise manufacturing method enables engineers to create tiny and intricately designed parts that find applications across various aerospace, automotive, and biomedical industries. The increasing demand for micro-electromechanical systems (MEMS), including actuators and sensors, underscores significant micro-manufacturing techniques while producing these components. Metal-based micro-manufacturing techniques often involve material deposition at an atomic level utilizing the electrodeposition principle, ensuring precise and accurate features. To achieve effective micro-manufacturing, specialized machinery equipped with high-accuracy motion systems capable of sub-micron resolution, high-speed spindles, and miniature-cutting tools are essential. These advanced tools and systems enable the demanding requirements of micro-manufacturing processes, ensuring the production of high-quality micro components.

Metal-based micro-manufacturing, utilizing the electrodeposition principle, can be executed through various processes, namely mask-based electrodeposition and maskless electrodeposition. Examples of mask-based electrodeposition processes include LIGA (German acronym for Lithographie, Galvanoformung, Abformung) and EFAB (Electrochemical Fabrication). On the other hand, examples of mask-less electrodeposition processes include Localized Electrodeposition (LED) and Selective Jet Electrodeposition (SJED). Mask-based micro-manufacturing techniques, such as LIGA and EFAB, face significant challenges due to the requirement of masks for each layer of deposition. These techniques often involve various hazardous chemicals, rendering them costly and environmentally unfriendly. The slow material deposition rate and high energy consumption are significant challenges of mask-based micro-manufacturing approaches. A mask-less electrodeposition method called Selective Jet Electrodeposition (SJED) is developed to address the challenges encountered with mask-based electrodeposition processes. SJED enables material deposition atom-by-atom, offering several advantages over traditional mask-based techniques. By eliminating the need for masks, SJED simplifies the manufacturing process, reducing production costs and environmental impact associated with mask fabrication and disposal. Additionally, SJED allows for greater flexibility and precision in material deposition, enabling the creation of intricate geometries with high resolution.The SJED experimental setup has been designed and developed in the present study to fabricate micro-features. The developed setup consists of several subsystems: a power supply unit, tool and workpiece holding unit, electrolyte circulation unit, and a CNC controller for precise movement. The electrolyte container is made of Perspex, a non-conductive and non-reactive material; hence, there is no charge loss during the process. A fixture is also developed to hold and provide a power supply to the workpiece.

The computer-aided process planning (CAPP) developed for the SJED setup involves three steps: preprocess, in-process, and post-process, aiming to facilitate the separation of micro parts from the substrate. This separation is challenging due to the strong chemical bond formed during deposition.Experimental investigations for nickel and copper considered parameters like applied voltage, scanning speed, and inter-electrode gap to achieve uniform deposition. Optimized parameters from single-bead experiments were used for multi-bead deposition, further refined by adjusting center distances between beads to achieve a flat surface.Various toolpath strategies were studied, including Space-filling Curves (SFCs) and a Traveling Salesman Problem (TSP) based solver. These strategies aimed to optimize part properties and process efficiency. The TSP approach helped create toolpaths with density gradients, where high grid point concentration resulted in denser material deposition.Using these optimized toolpaths, gradient-based microstructures of nickel and copper were deposited. A thick coating developed with these strategies was compared to conventional techniques, demonstrating the SJED setup's effectiveness for micromanufacturing and coating purposes.