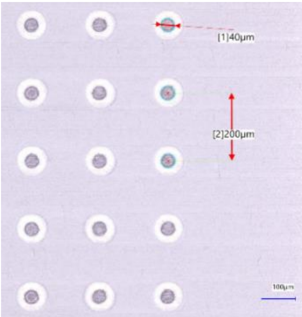
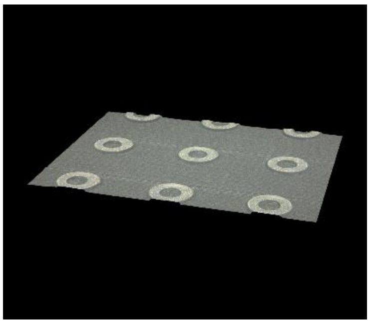
May 28, 2024
Elephantech Inc.

Announcing NeuralJet™: High-precision inkjet manufacturing technology using AI

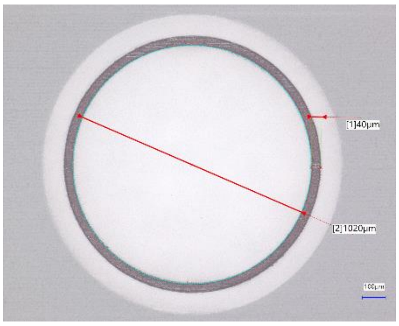
NeuralJet™ is a high-precision inkjet manufacturing technology achieved through advanced control techniques and AI. Rather than individually modeling the numerous error factors such as print operation errors, nozzle individuality, head assembly errors, and nozzle state changes, a single AI model absorbs them all. This enables high-precision ejection using general-purpose piezo chips while achieving a technical configuration suitable for mass production and widespread adoption. Elephantech will start mass production of printed circuit boards (PCBs) using this technology from 2025, and will also expand into applications other than PCBs such as semiconductor post-processes and displays.



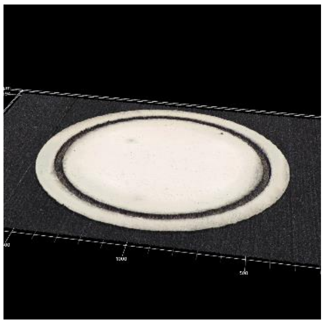
Filling ϕ40μm circular wells



3D imaging of ϕ40μm circular wells



Filling 40μm wide circular grooves



3D imaging of 40μm wide circular grooves

Key Feature 1: Ultra-high precision inkjet technology using general-purpose piezo chips

Using a proprietary printer with general-purpose piezo chips, extremely high printing accuracy has been achieved, such as "average drop position error of less than 2μm[1]" and "100% drop landing of 20μm droplets into 40μm grooves and wells[2]".

Key Feature 2: Integrated proprietary AI model that runs on local computing resources

Rather than modeling and solving individual errors, a proprietary integrated AI model models and absorbs all types of errors. By having AI learn and correct for process and assembly variations in MEMS and more, high accuracy is achieved while building a lightweight model that runs on local computing resources[3].

Key Feature 3: Fluid control and machine control optimized for easy AI modeling

Unlike the previous paradigm of "achieving absolute accuracy", fluid control and machine control optimized for "ease of AI modeling" enable high accuracy with a lightweight model.

Key Feature 4: Practical manufacturing system backed by mass production experience

Leveraging the experience of being the only company in the world[4] to successfully mass-produce PCBs using inkjet printing of metal nanoparticle ink, a practical manufacturing system usable in mass production sites has been built.

[1] Average drop landing error of 1.74μm (validation set not used for learning) for 643 droplets randomly placed within an 80mm square work.

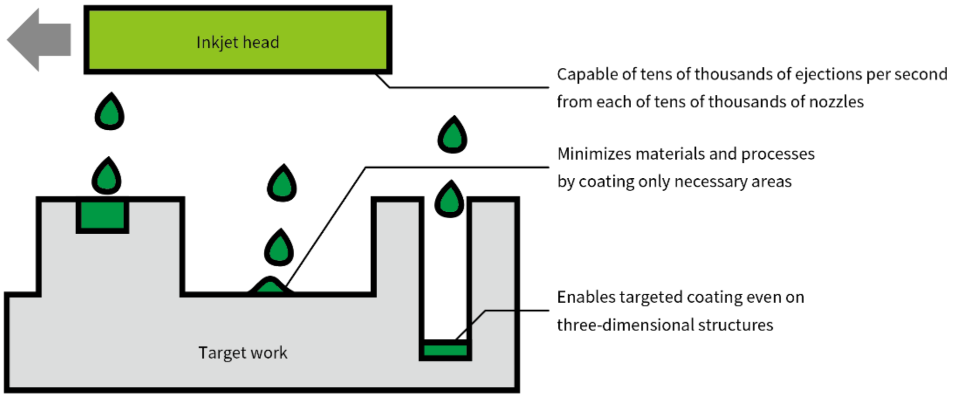
[2] 2596 points of 4.8pL droplets ejected into 40μm wide grooves with no adhesion outside the grooves.

[3] GPU etc. corresponding to equipment scale required.

[4] Elephantech research, as of announcement date.

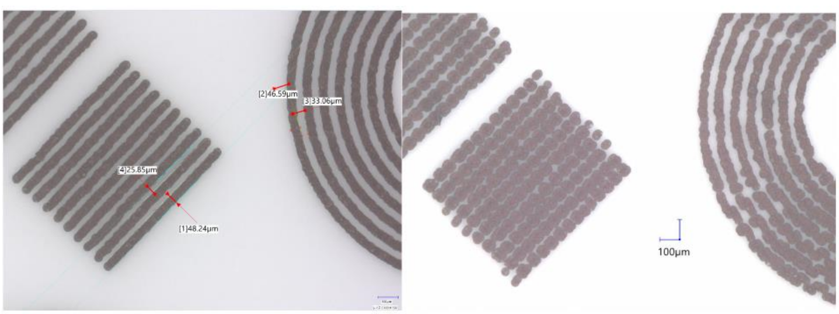
Key Feature 1: Ultra-high precision inkjet technology using general-purpose piezo chips

Inkjet is a unique technology with strengths such as non-contact ability to eject microdroplets of a few pL at speeds exceeding billions of drops per second, only where needed and in the required amount, and the ability to coat even on non-flat surfaces.



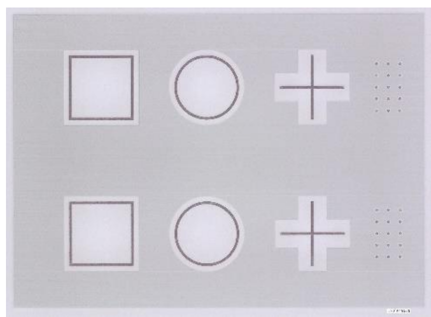
What becomes possible with high-precision inkjet

However, one challenge for inkjet has been achieving high accuracy in mass production. There have been attempts at ultra-high precision inkjet printing with accuracy below 5µm at the research level and in some commercial applications, especially in display manufacturing. But many of those attempts required specially designed piezo chips or were extremely difficult to adjust, and in any case, inkjet technology was not robust enough for use in manufacturing.
On the other hand, Elephantech has consistently developed high-precision and practically usable equipment for the PCB field which demands high robustness, using general-purpose piezo chips. By simultaneously owning and operating a PCB mass production plant, we have developed inkjet printing technology that can actually be used "in the field".
This NeuralJet™ technology, leveraging that mass production experience, is a high-precision inkjet manufacturing technology that can be used from prototyping to mass production, realized through advanced fluid control and AI-powered ejection control. It achieves very high accuracy while utilizing general-purpose piezo chips. The thinking is vastly different from both conventional general inkjets and ultra-precision inkjets - it is designed with AI utilization in mind and robustly achieves high precision.



NeuralJet Conventional

Comparison of print results with and without NeuralJet™ on the same printer



Filling 40µm wide rectangular grooves, circular grooves, cross-shaped grooves, and circular wells

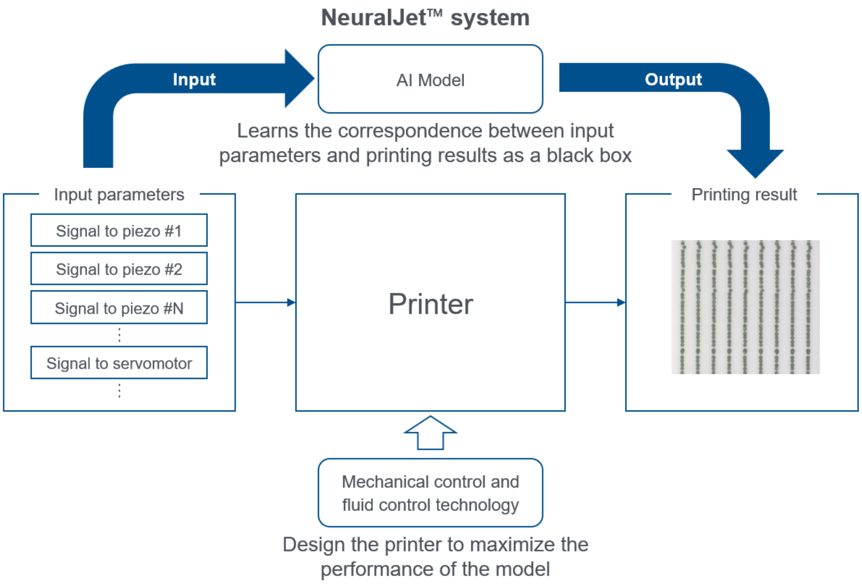
Comparison of NeuralJet™ with existing technologies

	General inkjets	Previous ultra-precision inkjets	NeuralJet™
Drop landing guarantee	Probabilistic drawing assuming misses of tens of µm per drop	Drop-level landing guarantee	Drop-level landing guarantee
Actual drop landing accuracy	Tens of µm	~Below 5µm	~Below 5µm
IJ piezo chip	General-purpose	Dedicated, normally requiring error below a certain level	General-purpose
Head alignment	Minimal	Very high precision required	Not required(*1)
Parallelism of each motion axis	Minimal	Very high precision required	Not required(*1)
Adjustment during machine setup	Easy	Very strict adjustment needed	Easy. Only model update, no mechanical adjustment needed.
Readjustment when changing heads	Easy	Very strict adjustment needed	Easy. Only model update, no mechanical adjustment needed.
Approach to dead nozzles	Complemented by surrounding nozzles	Complemented by separate nozzles, but basic idea is to avoid dead nozzles	AI explores optimal complementation, so a certain level of occurrence is not an issue
Support for large work (0.5m~)	Easy	Achieving high precision across large work becomes exponentially difficult	No relation between work size and accuracy, expandable as much as measurement accuracy and computation allows
Approach to fluid control	Control while allowing some error	Control so all dots are ejected without error	Allow inter-dot error and control to minimize long-context effects that AI struggles with
Approach to machine control	Control while allowing some error	Control so all dots are ejected without error	Allow inter-dot error and control to minimize long-context effects that AI struggles with

*1: Nozzles need to be within minimal tolerances to actuate properly in the desired print area, but no adjustment mechanisms are needed.

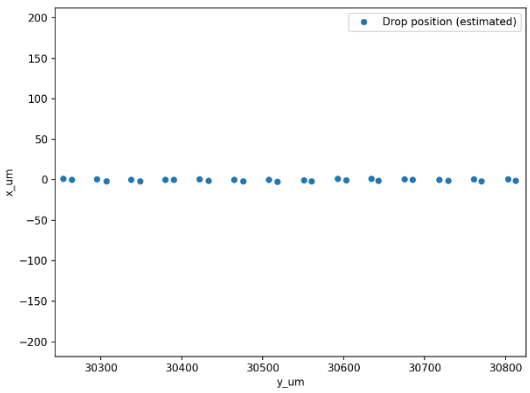
Key Feature 2: Integrated proprietary AI model that runs on local computing resources

In NeuralJet™, a single model absorbs all error factors - mechanical, electrical, and fluidic. Previous high-precision inkjets, like many high-precision industrial machines, identified individual errors, analyzed each one, and solved them. In contrast, NeuralJet™ does not analyze individual error factors or create models for each one, but learns them all with a single model.



For example, nozzle alignment, which is always performed in high-precision inkjets, becomes unnecessary. The left figure below plots the estimated landing position differences when the same input is given to all nozzles, using a model learned from actual printing operations (left-right is nozzle row direction, up-down is scan direction). This printer actually uses two rows of piezo chips, odd and even nozzle rows, and the landing positions differ slightly for each row. Even though the model is not told it uses 2-row chips, it models the 2-row chips and corrects the error. By having an integrated model learn such errors appropriately without individually modeling them, high accuracy is achieved.

We developed this model in-house. It is a lightweight model that can be learned and executed using local GPU/CPU computing resources, enabling relearning offline at any time in manufacturing sites. The accuracy and computation vary based on the data size used for model learning, but learning succeeds with computation processable by local resources, as shown in the right figure. The true performance value can be seen converging to an average error of less than 2µm.

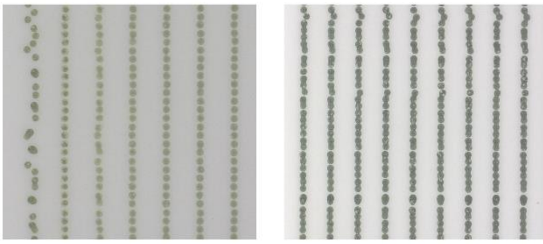


Learned landing characteristics of 2-row chips

Accuracy improvement by training data size

Key Feature 3: Fluid control and machine control optimized for AI learning

Using AI does not mean control is unnecessary. Achieving µm-level accuracy for large work requires advanced fluid control and machine control. However, the approach is vastly different from traditional control. Rather than "minimizing absolute error", the focus is on controlling in a way that is "easy for AI to model", and the equipment itself is designed with that premise. More specifically, the focus is on "minimizing errors that AI struggles with (typically long-context errors)". For example, the photos below show the same printer printing with different control, and while both have deviations from the ideal position, one state is difficult for AI while the other can be nearly perfectly modeled. This technology was realized through the cooperation of AI optimization and traditional optimization in this manner, with our advanced fluid control and machine control technologies being key.



Difference in ejection state due to control

Key Feature 4: Practical manufacturing system backed by mass production experience

We are the only manufacturer in the world to successfully mass-produce PCBs using inkjet printing of metal nanoparticle ink. We have in-house not only the equipment but also the mass production process, supplying finished PCBs to many customers.

ELP03 mass production machine in operation

Mass production is very different from research-level production, requiring high process capability with short downtimes. In NeuralJet™, adjustments during head replacement and maintenance also do not require manual adjustment, only model updates, realizing a simple mechanism that can guarantee consistent accuracy regardless of the operator.

Also, as the equipment scale expands and the number of nozzles increases, nozzle failure rates rapidly rise. Therefore, a system robust to nozzle state changes is necessary. In NeuralJet™, AI considers the current nozzle state and designs the optimal ejection path, making it resilient to nozzle state changes. For example, the 40µm groove and well printing results shown at the beginning were deliberately printed using a worn-out head with about 2% of all nozzles no longer functioning properly, but droplets were still successfully placed in all locations even in that state.

Future developments and contact information

This technology is fully scalable from prototyping to mass production. The development equipment NeuralJet™ L is already operational in our lab, and the production equipment NeuralJet™ P is scheduled to start operation from April 2025. In parallel, we will also develop custom manufacturing processes using this technology for semiconductor post-processes, displays, and more. If you are interested, please contact our Solutions Sales Department.

NeuralJet™ Machines

	NeuralJet™ L	**NeuralJet™ P**
Purpose	Laboratory use	Production use
Piezo inkjet chip	EPSON PrecisionCore	EPSON PrecisionCore
Work size	300x300mm	830x500mm
Work alignment	Arbitrary N points camera alignment[1]	Arbitrary N points camera alignment
Model learning	Local GPU/CPU	Local GPU/CPU
Takt time per pass	15sec for 300mm scan	5.3sec for 830mm scan
Pass scanning width	60mm	500mm
Footprint	1.2x1.2x1.6m	5.0x5.0x2.4m
Weight	500 kg	15 ton
Status	Working in our lab	Starting production from April 2025

※1: Alignment using an arbitrary number of points with arbitrary coordinates

Company Overview

Name	Elephantech Inc.
Establishment	January 2014
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Business Description	Development of printed electronics manufacturing technology and provision of related services
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