NanoPrintek
DRY MULTIMATERIAL PRINTER

	Ink-Based Printing Technology	VS NanoPrintek
Material Cost	Silver ink: ~$300-500 for 100ml. Cu-Ni ink: ~$1,200 - $1500 for 100ml ZnO ink: ~$1,000-5,000 for 5-100ml depending on quality	**10-100X** less depending on the materials
Material Options	**Limited printable inks**, such as silver, copper, and a few alloys like Cu-Ni	Many (metal, semiconductors, insulators, composites, ceramics, etc.)
Maintenance	Regular and daily machine cleaning for printing and **after each use** (sometimes >50 parts).	**Very low** / no maintenance
Cleaning	Cleaning **required after each use**. AJP consists of many parts that need to be assembled and disassembled every time for cleaning.	**Very low** / Occasional wiping
Energy Use	**Very high!** Could be as high as multi kilowatts.	**<1000W** for the entire system
Space Required	Very large! could be **>36x60x96 inch** (W,L,H) and >**2000 lbs**	~24x24x35 inch (W,L,H) and **<200 lbs**
Pollution	Utilizes **hazardous solvent** and requires a **pollutive** and energy/water-consuming process	**Eco-friendly** manufacturing
Supply Chain	**Complex supply chain**: nanoparticle manufacturing, ink manufacturing, post-processing	On-demand **nanoparticle generation** and **real-time sintering** process

Through extremely low material cost, very little required maintenance , and real-time sintering, NanoPrintek printers can save $100,000 - $200,000 in one year of use compared to other printing methods as well as being significantly friendlier to the environment.

Other Challenges With Ink-Based Printing Technology

1) To prevent contaminations, it is better to allocate distinct print modules for different materials (no cleaning process can guarantee no residues of previously printed material). **Each print module costs ~$20,000-$40,000.**

2) The viscosity plays the most important role in AJP. A small change in viscosity will result in changing the print outcome. **Reproducibility is extremely challenging** to achieve with AJP. Constantly measuring the viscosity not only requires expensive instrumentations ~$10,000 to $100,000, but also requires spending an **extensive amount of time** for measuring and characterizing.

3) The AJP process **highly depends on the temperature of the solvent and ink** (which needs to be determined). For example, the temperature of a highly volatile solvent such as thinner for dielectrics needs to be ~20 °C. A small change of ~0.2 °C in the temperature changes ink viscosity. The changing of temperature is likely to happen due to multiple reasons, including; 1) the heat from the substrate (often used for decreasing the linewidth or sintering the lines) can change the temperature in the print module since their separation distance is ~5 cm while printing, 2) Other situations might affect the temperature such as a bad chiller, pipe leaks, or room temperature variation.

4) The solvents are usually kept in a bubbler (the part's name). During the printing process, the **solvent level keeps changing**, which changes the printing condition and varies the print thickness. A lower level of solvents makes the printing dryer and more overspray. Higher solvents make the print too wet, so the printed ink spreads on the substrate.

5) Inks have a **very short lifetime,** usually between 3 months to 1 year. During this time, their viscosity will also change, making them challenging for reproducible and reliable prints.

6) For printing smaller line widths, a new set of modules with a new kind of ink with less viscosity must be designed (less than 10cp for less than 30um, 10 to 1000 cp for more than 30um). **This means more cost, more printing process, and new challenges.**

7) There is no way to measure the resistance in situ due to the unfinished print and the need for post-processing to sinter the lines, which takes at least 3-4 hrs. Thus, after 3-4 hours, the ink has already settled down in the print module, so there is no guarantee that the same results can be achieved after resuming the process. Trying the print another day, the same (or even more) challenges will exist. **This means repeatability/reproducibility is challenging in this technology.**

8) **The number of reliable inks is very limited.** It is very challenging and often impossible to find inks for any desired materials. Almost all ink manufacturers make limited printable inks, such as silver, copper, and a few alloys like Cu-Ni. The multifunctional materials printed by AJP are still rudimentary. Developing a new ink usually takes years and requires huge investments to get even one new ink (let alone printability, reproducibility, and reliability).

9) The ink-based printing technologies are **not environmentally friendly.** Hazardous solvents need proper disposal protocols (a new disposal company needs to be involved, adding more expenses).

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