

# Waste Reduction in Hard Disk Drive Manufacturing by Improving Solder Jet Bonding Efficiency

## การลดปริมาณของเสียในกระบวนการผลิตฮาร์ดดิส์กไดร์ฟ โดยการปรับปรุงประสิทธิภาพการเชื่อมวงจร โดยวิธีการพ่นลูกโลหะผสม

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### ABSTRACT

Solder jet bonding (SJB) of head gimbals assembly (HGA) manufacturing was investigated through the effects of coating agents and coating sequence. Coating agents such as titanium nitride (TiN) and titanium aluminium nitride (TiAlN) were focused on. The coating thickness for both single and multiple layers was limited to 1  $\mu\text{m}$  (max). Coated tips were characterized by focus ion beam (FIB) and scanning electron microscopy (SEM) techniques. It was also tested for the reliability of usage. It was found that coating sequence of TiAlN following with TiN provided much more durable life span ( $> 0.88$  million uses) compared to the control one (ca. 0.50 million uses). Tips coated with either single layer of TiN or TiAlN did not give significantly difference in their life spans. The tip coated TiAlN-TiN reduced process downtime more than as it was about 8–10%, which mainly reduced solid waste 0.45 ton/day of waste generated in hard disk drive manufacturing.

### บทคัดย่อ

การเชื่อมวงจรในการผลิตหัวอ่าน-หัวเขียนโดยวิธีการพ่นลูกโลหะผสม ถูกตรวจสอบผลผ่านสารเคลือบผิวและลำดับของสารเคลือบผิว โดยมุ่งเน้นที่สารเคลือบผิวชนิดไททาเนียมไนไตรด (TiN) และไททาเนียมอลูมิเนียมไนไตรด (TiAlN) ความหนาของสารเคลือบทั้งประเภทการเคลือบแบบชั้นเดียว หรือการเคลือบแบบหลายชั้นถูกจำกัดที่ความหนาสูงสุดที่ 1 ไมครอน ลักษณะของ tip หลังจากผ่านการเคลือบผิวทดสอบด้วยเครื่องไฟฟ้าอ่อนนึ่ม (FIB) และกล้องจุลทรรศน์อิเล็กตรอน (SEM) และ tip หลังผ่าน

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การเคลือบก็ได้ถูกทดสอบความน่าเชื่อถือผ่านการใช้งาน การทดสอบพบว่าลำดับของสารเคลือบของไทยเนียมอลูมิเนียมในไตรดตามด้วยสารเคลือบทาเนียมในไตรด ให้อายุการใช้งานสูง โดยรอบการยิงลูกบลล อยู่ที่ 880,000 ครั้ง เมื่อเปรียบเทียบกับ tip ที่ไม่ได้ผ่านการเคลือบซึ่งจะมีรอบการยิงลูกบลลที่ประมาณ 500,000 ครั้ง Tip ที่ผ่านการเคลือบแบบชั้นเดียวของไทยเนียมในไตรดหรือไทยเนียมอลูมิเนียมในไตรด ไม่ได้ให้ผลแตกต่างอย่างมีนัยสำคัญในเรื่องอายุการใช้งาน Tip ที่ผ่านการเคลือบผิวด้วยไทยเนียมอลูมิเนียมในไตรด-ไทยเนียมในไตรด ลดเปอร์เซ็นต์การหยุดการทำงานของเครื่อง SJB มากกว่าร้อยละ 8-10 ชั่งสามารถลดของเสียที่เกิดขึ้นในกระบวนการผลิตสารดิสไทร์ฟประมาณ 0.45 ตันต่อวัน

**Key Words :** Physical vapor deposition (PVD), Head gimbals assembly (HGA), Solder jet bonding (SJB)

**คำสำคัญ :** การตอกตะกอนไออกสารทางกายภาพ หัวอ่าน-หัวเขียน การเชื่อมวงจรหัวอ่าน-เขียนวิธีการพ่นลูกโลหะผสม

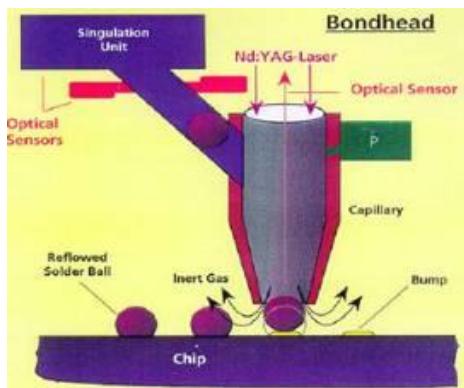
## Introduction

Clean technology has been applied to electronic manufacturing for two decades. The improvement is still in every square inch in this particular company. The existing electronic circuit soldering has moderate life span, around 0.5 million shots of use. The process line has long downtime almost every day, contributing a lot of waste around 0.45ton/day. To reduce the waste and time of replacement, electronic circuit soldering is required for the improvement. The electroplating of finishes, such as hard chromium, cadmium and nickel in metal finishing is today recognized as a major source of environment pollution in every country. Therefore wet batch technologies have started to lost favour compare with dry coating methods such as physical vapour deposition [1].

A dry coating by PVD technique, namely solder jet bonding (SJB), has been performed well regarding to low environ-

mental pollution, compared to a wet coating technique. Soldering is a well established joining technique, omnipresent in electronic industry. Solder techniques and the kinetics of the solid/liquid reaction have been studied intensively in recent year [2]. SJB seems to be a new technology for electronic circuit soldering in electronics industry. It is used in assembly line of a Hard Disk Drive company by applying the coating process. The SJB schematic is shown in Figure 1. The process that connects slider to suspension circuit pads with solder. The solder ball is molten by laser and jet onto the pads, and then nitrogen gas is used to cool down dramatically molten solder. However, the yield is not much different from the existing electronic circuit soldering technique. Besides, the SJB is still a bottle neck section for the mechanical yield and productivity in Head Gimbals Assembly process (HGA). Since the tip has to be replaced from time to time, the yield

therefore lost in a large quantity. The defects relating to dispenser tip failure and failure mode of the tip were investigated in this study. The life time improvement of disperser tip was also considered.



**Figure 1** Solder Jet Bonding (SJB)

Productivity obtained from wet and dry coating processes. The study was done using tungsten carbide tips coated with a thin layer. The process was very dangerous for both workers and the environment [3]. An “ion plating” may provide much less polluting and much higher efficient. The process required a high vacuum chamber, an electric arc, assisted by a magnetic field, transforms a coating material into a “plasma” – that means into an ion vapor – and the vaporized material are spread onto the surfaces to be coated through a “bombing” process. The ion plating process is preceded by cleaning-drying of the surfaces to be coated. The drying process is based on a thermal vacuum process, which generates no waste. The multilayer and single layer PVD coating on tool by several metals, like Ti,

Al, Si et al., was also studied. Those layers allowed a great deal on thermal resistance and self lubrication [4].

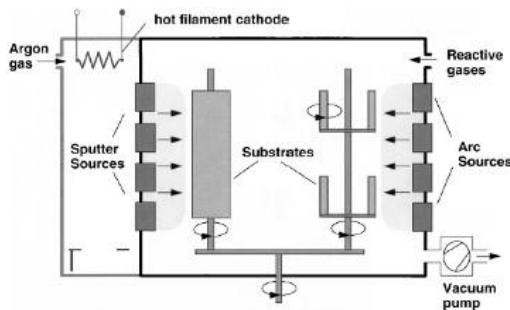
In this study, we intend to investigate practically on the coating agent in dry coating process. Two chemicals as titanium nitride (TiN) and titanium aluminum nitride (TiAlN) were selected for both single and multilayer studies. Throughout, the characterization and product’s life spans were also included.

## Methodology

Dispensing tools were used for testing samples. The coating process for internal hole of dispensing tool was carried out. Laser type of Nd:YAG was used in the solder jet bonding process. Physical Vapor Deposition (PVD) produce metal vapor to deposit thinly on electrically conductive materials. It was carried out in a high vacuum  $10^{-6}$  torr chamber using a cathodic arc source. The parameters of four different PVD coatings are presented in Table 1

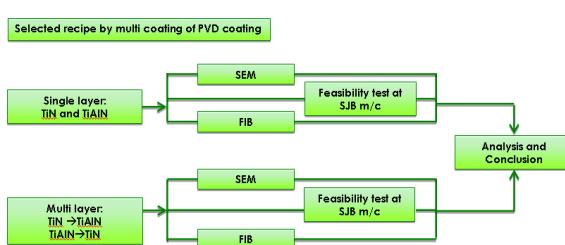
**Table 1** PVD coating parameters

Code	Layer (in->out)	thickness ( $\mu\text{m}$ )	Composition
TiN	TiN	$1 \pm 0.5$	70%Ti, 30%N
TiAlN	TiAlN	$1 \pm 0.5$	50%Ti, 50%Al, N
LX	TiAlN	$1 \pm 0.5$	50%Ti, 50%Al, N
	TiN		
LY	TiN	$1 \pm 0.5$	70%Ti, 30%N
	TiAlN		



**Figure 2** schematic of the PVD coating process

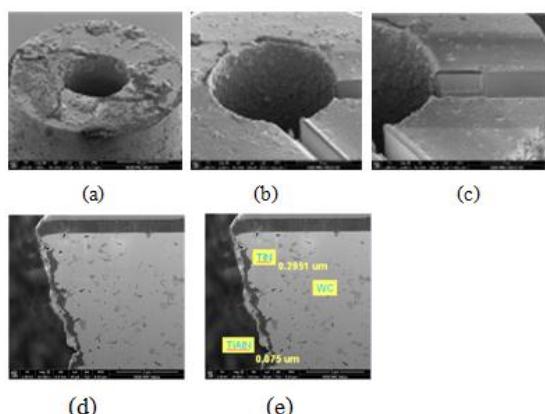
The arc evaporation process begins with the striking of a high current, low voltage arc on the surface of a cathode (known as the target) that gives rise to a small highly energetic emitting area known as a cathode spot. The localized temperature at the cathode spot is extremely high (around 15,000 °C), which results in a high velocity (10 km/s) jet of vaporized cathode material, leaving a crater behind on the cathode surface, as shown in Figure 2. The arc has an extremely high power density resulting in a high level of ionization. The interaction with the ion flux and a compound film will be deposited [5]. A roadmap of this experiment could be summarized in Figure 3.



**Figure 3** Roadmap of SJB development

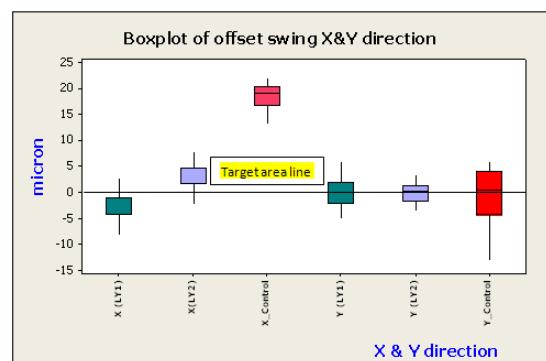
## Results and Discussion

The PVD process has been applied successfully on the soldering dispenser tip. Figure 4 shows the series of the dispensing tool before and after the coatings. The coating with required thickness (ca. 1  $\mu$ m) could be carried out in both single (TiN or TiAlN) and multiple layers (TiN–TiAlN and TiAlN–TiN) by the present technique. All samples were tested for the offset swing. Examples for TiN–TiAlN coating, it was found that the coated samples provide less deviation from the target (only 0.2–2.0 micron in both axis) compared to the controls, as shown in Figure 5 position error of the solder jetting both X and Y direction. The control was normally away from the set point in X axis to approximately 15–20 micron.



**Figure 4** Images of dispensing tool in each step by Focus Ion Beam technique; a) dispensing tool, b) after the PVD, c) after the PVD (close-look), d) and e) X-section and thickness of TiN–TiAlN multilayer coated

The results based on TiAlN–TiN coating were similar to those by TiN–TiAlN coating. However, the multiple layer coating had less offset swing than single layer coated materials. Sample by different coating method were tested in a research-line, analogizing to the real practice. The result of dispenser nozzle lifetime shows the number of lifetime versus the coating material types both single and multiple coating in Figure 6. All coating materials exhibited the longer life span than existing tool (uncoated) by 20–77% improvement. Especially on multilayer coating, longer life span was provided vice versa the single coated tools. The longer life span, the more process downtime is expected. Figure 7 shows the downtime percentage of the process. The data was collected in weekly basis. It was found that downtime was much high with uncoated tools, while coated tools (TiAlN–TiN) presented low possibility of downtime, as expected. Certainly, the waste would be generated less since there was not many replacements had been made. The detail data would be provided in the presentation.



#### Descriptive Statistics: Offset

Variable	XY	N	Mean	StDev
Offset	X (LY1)	30	-2.189	2.620
	X (LY2)	30	2.967	2.449
	X_Control	30	18.467	2.387
	Y (LY1)	30	-0.000	2.846
	Y (LY2)	30	-0.152	1.873
	Y_Control	30	-0.608	5.218

Figure 5 Box plot of offset swing at X&Y direction

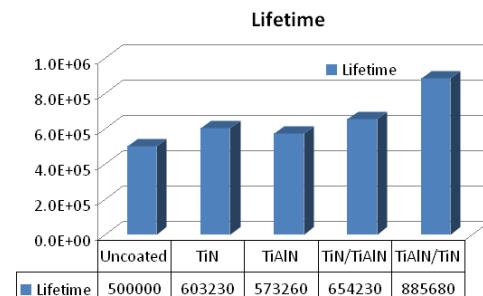
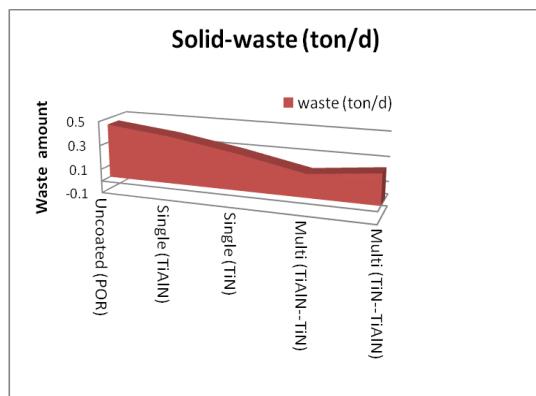


Figure 6 Lifetime comparison between single and Multilayer coating

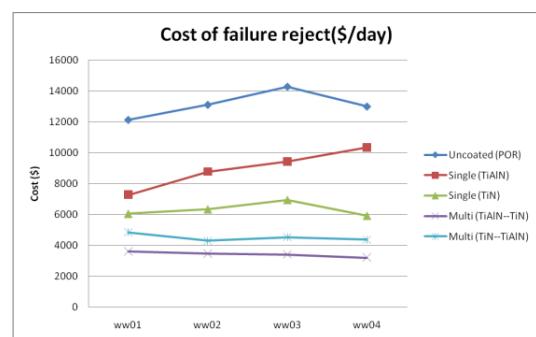


Figure 7 %Downtime at SJB m/c after install evaluated test piece

Base on the data from research line, Waste amount from SJB process with Multi coating tip could decrease waste to 0.19 tons/day, as shows in Figure 8. We observed 65% of cost improvement when install the test pieces with multi coating refer graph shows in Figure 9



**Figure 8** Waste amounts at SJB process from each tip condition



**Figure 9** Cost of failure reject at SJB process from each tip condition

## Conclusion

Coating the tools by dry process of PVD coating with TiAlN-TiN at thickness 0.5 and 0.5  $\mu\text{m}$  provided better tool strength

and thermal resistance. Life span of its improved more than 60-70% compared to the control one. It also promised the lower process downtime. Therefore, PVD with TiAlN-TiN is quite promising for the clean technology in term of less waste generated and cost effective.

## Acknowledgements

The authors specially wish to acknowledge Western Digital for support all needed chemicals and facilities.

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