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Solder Bridging Rework Simulation on Connector of TuMR Magnetic Head

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Abstract. In the Hard Disk Drive manufacturing process, the assembly yield is the most important thing to reflect the manufacturing cost and profit. The manufacturing engineers tend to improve the process yield continuously. The optimized parameters, working procedure improvement and equipment development are applied to reach the highest yield and lower the rejected part. The rework process is a good idea to gain back yield from rejected part. But the reworked parts must pass many test criteria to guarantee same product performance. This work will study an opportunity of cost improvement in Hard Disk Drive manufacturing.

Keywords: Head Gimbals Assembly (HGA), TuMR, Pin Layer Reversal (PLR), Solder Jet Bonding (SJB), Inter-metallic Diffusion

1. Introduction

This work propose the rework study on HGA solder bridging defect which is major reject problem in HGA solder Jet Bonding process This paper will show about how to study about the defect, impact parameters and simulate heat pattern to rework the Head Gimbals Assembly. In this paper, we will consider the Pin Layer Reversal (PLR) of magnetic reader, connector gold platting surface diffusion and spattered solder from boiling. For the other parameters such as the MRR, Asymmetry and fly height, we will use standard in process of Head Gimbals Assembly to qualify the rework part. The rework concept will use the reheating and removal force to remove the solder bridging problem. The reason to use this process because the process that use to soldering the HGA is laser pulse heating and the chemical and mechanical process will impact the product reliability and higher risk than re-heating process. The chemical process will impact the corrosion and out-gassing of product and the mechanical process will not suitable for the product in the future because the force can damage the micro actuator and mechanical properties of the product. This work will consider the TuMR reader type on Femto product revision. For the suspension arm, this work will consider the TSA plus which is the deposited process. For the solder material, this paper will consider the SAC305 which use in Head Gimbals Assembly. [3]The major elements of this material are Tin 96.5%, Silver 3.0% and Copper 0.5%. The melting temperature of this SAC material is 215 degree Celsius and the boiled temperature is 2602 degree Celsius (assume tin boiled point[11]). The simulation will be done on ANSYS version 12.0. The transient heat transfer is applied to simulation. For the heat source for rework, the ND:YAG laser is used in rework process. This laser commonly uses in solder jet bonding process and it robust to do rework too. For the shield of soldering, this rework process use nitrogen which use in solder jet bonding process to prevent the oxidation surface.

2. Theory and Equations

2.1. Diffusion of Gold

[1]The connector of the Head Gimbals Assembly normally made from copper and plate with gold. The nickel layer may be added as the layer to improve the heat transfer for wetting ability. [9]The soldering process will make the inter-metallic which hard and brittle. The thick inter-metallic layer can be detrimental to solder joint reliability. The formation of the inter-metallic layer is related to time and temperature for a

given set of materials. The growth is the diffusion controlled process and can be represented by the following growth model: pad clean up (removal of residual solder). The equation of diffusion can be shown in equation 1 and 2

$$d = (D.t)1/2 \quad (1)$$

Where: d = inter-metallic layer thickness, D = diffusion coefficient, t = time

$$D = D_0.e^{(-Q/RT)} \quad (2)$$

Where: D_o=diffusion constant, Q=activation energy for inter-metallic growth, R=Boltzmann constant, T=absolute temperature
From the equation 1 &2 , we can consider the time and temperature as the key parameters of inter-metallic diffusion.

2.2. Pinned Layer Reversal of TuMR

The coupling energy is used to explain the minimum which is required for flip or change direction of magnetic field in a Ferro material. This energy can be explained by the equation 3. [2]From the equation, we can see the coupling energy depends on material type and the thickness of material. The temperature can change the exchange field or exchange bias of material. [3]The higher temperature can reduce the exchange field and at the blocking temperature, the exchange field will become to zero. The blocking temperature can be shown in equation 4. From the equation 3 and 4, we can conclude that the blocking temperature is depended on material and volume of material or thickness of material layer.

$$E_A = H_{EX}.M_S.t_{FM} \quad (3)$$

Where: E_A=Coupling energy, H_{EX}=Exchange field, M_S=Saturated Magnetization
t_{FM}=Ferro-magnetic material thickness

$$T_B = ((K_U.V/K_B).\ln(\tau/\tau 0))1/2 \quad (4)$$

Where: T_B=Blocking temperature, K_U=Anisotropy constant of material, K_B=Boltzmann constant,
V= Volume of concerned material, $\tau/\tau0$=Super-paramagnetic time ratio

2.3. Transient Heat Transfer

For the transient hat transfer, the solid parameters that vary follow the temperature are Conductivity Coefficient, Density, Emissivity and Absorption coefficient. For fluid, the non-linear parameters are specific heat constant pressure, Density, Viscosity and Film coefficient. The Thermodynamic laws are use to find nitrogen gas density and Sutherland equation[4] is use to calculate density. [5]The global equation of the rework system can be written in equation 5

$$\rho.Cp.\partial T/\partial t = Q - \nabla.(-k\nabla T) - h(T_e-T) - \varepsilon\sigma(T_a^4-T^4) + q_sT \quad (5)$$

Where: ρ=Density, Q=Heat source (laser), k=Conductivity coefficient, h=Film coefficient, ε=Emissivity, σ=Stefan Boltzmann constant, T_e=External Temperature, T_a=Ambient Temperature, q_s=Absorption coefficient

3. Experiment and Simulation Results

3.1. The Bridging Defect Analysis

In the Head Gimbals Assembly production line, the solder jet bonding defects are studied and classified by type of defect and observe the bridging pair percentage. The defect type result can be shown in figure1. The results show that the bridging defect is the highest percentage in all defect type. The details of defect are Bridging 36%, Burning 34%, Less bonding 24% and Missing bond 6%. This data is collected for a month. For the location analysis, the sampling was taken from 3 lines for a week. The sample was inspection under scope at 45 times magnification.

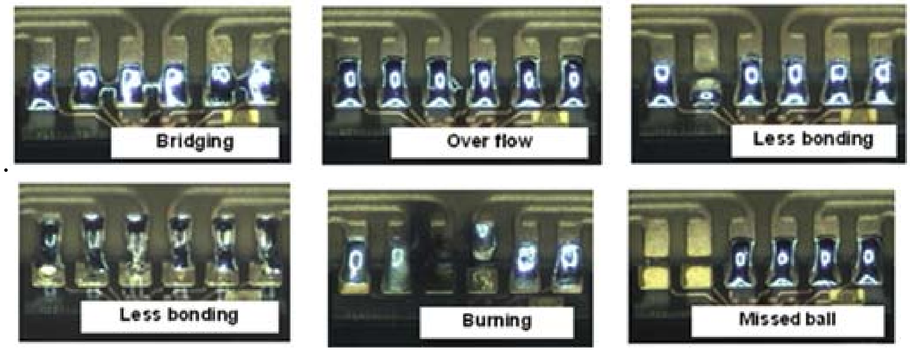


Fig. 1: The solder jet bonding defect type

The sizes of middle bridging core are classified by group size range. Group 1 is the size 0 to 22.5 micrometer. Group 2 is the size 22.5 to 45 micrometer. Group 3 is the size 45 – 67.5 micrometer. Group 4 is the size 67.5 to 90 micrometer. The bridging position is indicated by pair. The first pair is the bridging between the first and the second connector. The second pair is the bridging between the second and the third connector. The third pair is the bridging between the third and the forth connector. The forth pair is the bridging between the forth and the fifth connector. The fifth pair is the bridging between the fifth and the sixth connector. The result of bridging pair are pair1=29%, Pair2=16%, Pair3=22%, Pair4=23% and Pair5=10%. The result of bridging size can be shown in figure 2

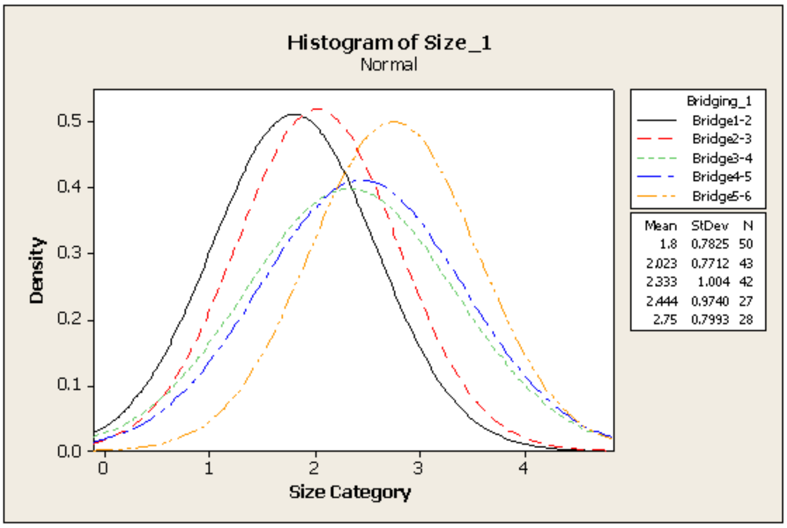


Fig. 2: The distribution of the bridging size by the bridging pair position

The result of bridging position show that the bridging can be happen at every pair without trend at some pair. And the bridging size analysis shows that the group 1 and group 2 of size category are about 70 % of bridging defect. From the experiment simulation by offset the target out from centre of connector show that this 2 category happen when the target of jetting has offset in range 20 to 30 micrometer. The more offset will create the bridging size in category 3 and 4.

3.2. Pin Layer Reversal and Reliability Test

The experiment is setup to find the maximum temperature limit on TuMR reader head by using the hot air blow to TuMR reader head which mount on Head Gimbals Assembly and put the thermocouple on head to measure the temperature. The Quasi test machine is use to determine the transfer curve of reader head the experiment. The temperature will be increased every 10 degree Celsius and measure PLR from 170 to 300 degree Celsius. The result of this experiment shows that 2 wafer start to have PLR at 190 degree Celsius and a wafer can observe PLR at 240 degree Celsius. The correlation summarize graph can be shown in figure 3.

The long term reliability tests are conducted by using PORM (Parametric Ongoing Reliability Monitoring test) and HFAT (High Frequency Amplitude Degradation Test). The Head Gimbals Assembly was measured PLR, Asymmetry and Resistance as control value then applied heat at temperature 180 degree Celsius for 20 seconds and measure parameter again. The HGA will pass PORM condition and measure controlled parameter again then pass HGA to HFAT and measure controlled parameters again. All parameters, before test and after test, are passed.

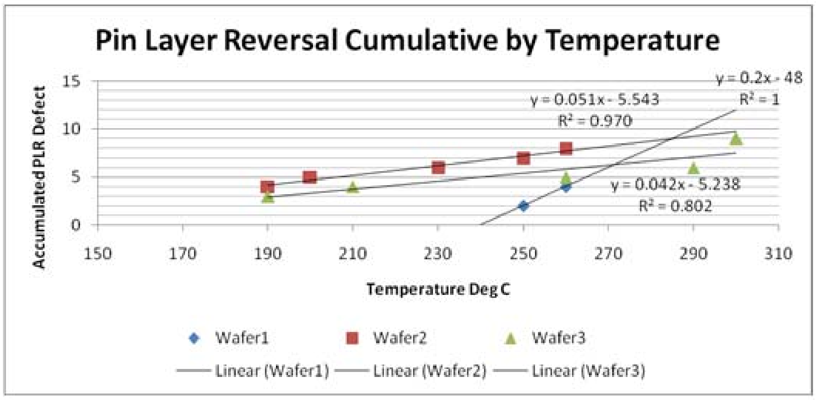


Fig. 3: The PLR and temperature on TuMR experiment summarize graph

3.3. The Diffusion Effect after Heating

The gold diffusion have effected to SAC305 after the solder receive high temperature. This phenomena can be proofed by the experiment which applied heat to the solder joint (SAC305) with different temperature around SAC305 melting point. The setting temperatures are 200, 220 and 240 degree Celsius for 10 seconds by hot air. The result of this experiment shows that the inter-metallic AU-SN is created and it impacts to solder strength by void occurrence. The void happen because the contamination under plating gold or the different strength and different expansion rate in material. The picture of void can be shown in figure 4a.

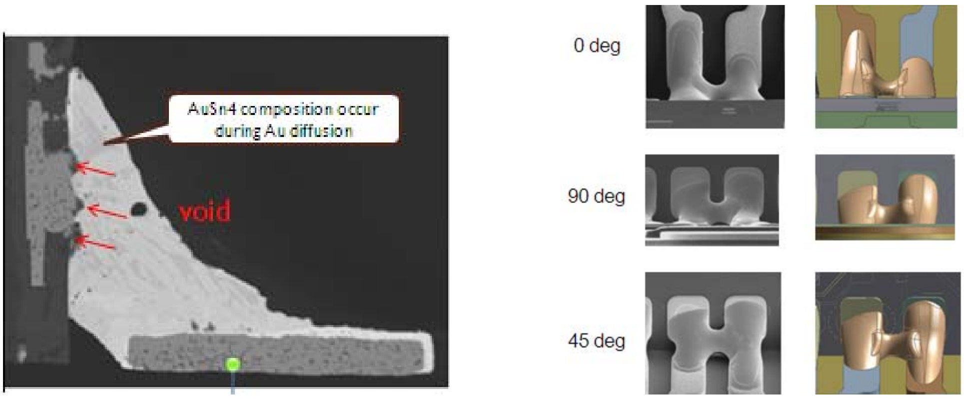
3.4. The Bridging Model Construction for Simulation

The model of group 2 bridging size at the third pair are created by use SEM scale image by different angle 0 , 45 and 90 degree. The grids are made at 20 micrometer on 400 magnification SEM image with scaling. The cross section at middle of the third connector, middle of the forth connector, middle of bridging core and the edge of the forth connector are include in modeling. This construct to be the model by using the evolve function in solidworks. The finished model passes the validation by using volume error and solder flow length. The validation result shows that the model has error 0.94% at the single bond and 2.8% at bridging bond. The errors are happen because the solder shrinkage marks during cooling down. The model comparisons are shown in figure 4b. The model is simulation by finite element analysis[7] to applied the heat flux to the problem solder. This heat flux will work as laser power that applied to rework process. The convection and radiation will applied to the area around the solder. And the conduction will applied to the material around the solder area. The non-linear co-efficient which applied in model are conduction and film coefficient. The film coefficient (convection coefficient) is calculated with nitrogen properties[8] and use laminar flow on the surface. The equation can be shown in equation 6. The thermodynamic equations are used for calculation nitrogen properties. [6]

$$h.L/k = 0.664Re^{1/2}.\ Pr^{1/3} \qquad (6)$$

Where: h=film coefficient, L=Contact length, k=conductivity coefficient, Re=Renolds number, Pr=Prandtl number

The result of simulation show that we need 2 laser pulses to heat up to desired temperature and the second laser pulse is used to maintain the temperature. The second laser power magnitude is depended on heat loss rate of the model. The validation of the model simulation will be on the next phase of working. The sample of two laser pulse simulation result is shown in figure 5. The optimization of the first pulse can be observed from the maximum temperature and the melting area on solder. The optimization of the second pulse can be observed from the stability of maximum temperature and target remove time during rework. This optimization can be observed in figure 5. The first pulse applies at time 0.5 to 1.0 millisecond and the second pulse applies from 1.0 to 3.0 milliseconds.



(a) (b)

Fig. 4: a:The void happen in SAC305 on gold plating surface, b: The bridging model validation

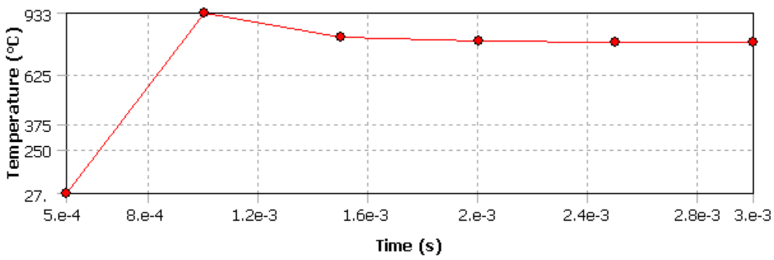


Fig. 5: The Maximum temperature profiles for 2 laser pulse

4. Conclusion

At this work, the constraints of the simulation model are defined and the model of bridging is constructed. The transient heat transfer formula is applied to model. The simulation shows how model respond the laser pulse. The two pulses give better temperature control than one pulse.

5. Acknowledgements

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