Investigation and Development of Air Bridges

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Abstract – **A study was done in order to develop a fabrication process for creating air bridges at RIT's Semiconductor and Microsystems Fabrication Laboratory (SMFL). Process development looked at three key factors (i) a robust lithography process that would produce the necessary rounded profile for fabricating air bridges (ii) sputter deposition vs. evaporation as metal deposition techniques (iii) the strength of the structures by testing the maximum distance an air bridge could span, the minimum and maximum thickness the structure could support, and the dimensions of the support posts. Several samples were fabricated testing the three different factors studied and SEM micrographs of the structures were taken for analysis. A baseline fabrication process was then created for use at RIT's SMFL.**

Index Terms – **air bridge, MEMS, free standing microstructures, high speed interconnects.**

I. INTRODUCTION

THE development of MEMS devices and the growing need for high speed interconnects in integrated circuit applications have called for the development of free standing microstructures known as air bridges. Many MEMS devices have facilitated the use of such structures in their design, while the need for lower frequency response in high speed integrated circuits make air bridges perfect candidates for simple interconnect systems due to the use of air as the separating dielectric medium. The ability to fabricate such structures are crucial in MEMS and high speed analog devices and thus the development of such a process will allow RIT and SMFL to further research in MEMS and high speed analog devices. Furthermore the low frequency response of air bridges due to the lowered capacitance in the line makes such structures viable candidates for high speed digital interconnects.

Simplicity is the key to process development as a simple process not only reduces the time required for fabrication, but also produces the most robust process due to the reduction in error in processing from a reduced number of steps.

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For the process developed at SMFL a simple two level lithography process was chosen. Several factors were of interest during development. Of particular interest to development were the strength of the bridge with respect to the bridge size and metal thickness and the lithography process used to define the shape of the bridge. A small DOE was conducted in order to determine how these process steps and structural characteristics affected the overall process. Development of this process will eventually be integrated into device fabrication.

II. THEORY & PROCESSING CHALLENGES

A. *Bridge Theory*

Continuing on the theme of simplicity the basic design of an air bridge is based on the simplest of all bridges, the arch bridge. Arch bridges have great natural strength and the simplicity of the design makes it ideal for microstructure fabrication. The physics of an arch bridge, which the design of the air bridge is based on, is the distribution of force throughout the bridge. There are several forces that act on a bridge that both work to keep the bridge standing and to bring the bridge down. A simple diagram of the fundamental forces acting on a bridge can be seen in Figure 1 [1].

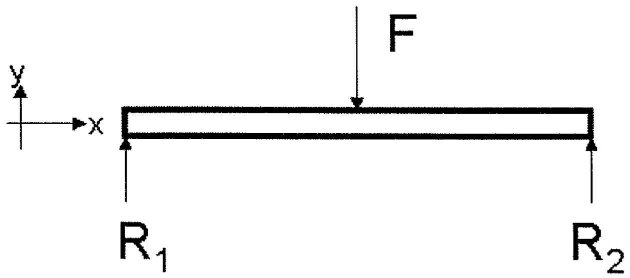


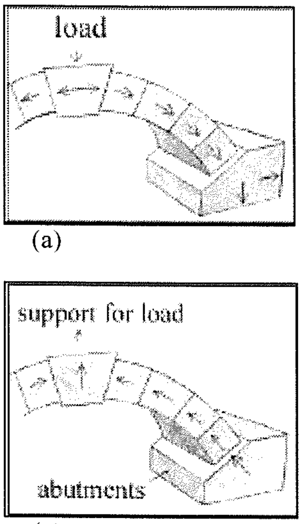
Figure 1: Basic Force Distribution on a Bridge

In order for the bridge to remain standing, an equal distribution of forces must be achieved. In other words the sum of all the forces acting on the bridge must be in equilibrium. Looking at Figure 1, there is a downward force, F, applied by the load of the bridge. This downward force is translated to the supports of the bridge, R_1 and R_2, which in turn exerts an opposing force to the force applied by the load of the span. As long as the force applied by the load is equal to the sum of the forces applied by the supports, the bridge will stand. This is mathematically illustrated on the following page.

$$SF_x = 0 \text{ and } SF_y = R_1 + R_2 - F = 0 \quad (1)$$

The fundamentals of the distribution of force in a bridge can be applied to any type of bridge made, and can easily be applied to the forces acting on an arch bridge, which the air bridges being fabricated are based on. In an arch bridge the weight of the span exerts a downward force on the bridge. This force is transferred along the span of the bridge and eventually translated over to the supports of the bridge. This force is then conveyed into the ground. In terms of the air bridge the downward force of the load will be translated into the substrate.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. It is this fundamental law that keeps the bridge up for the downward force of the span working to collapse the bridge is met by an upward force of the substrate acting in opposition. This force is transferred from the substrate onto the support posts, which in turn translates the force onto the span. This force is applied in the opposite direction relative to the force applied by the load and works to keep the bridge standing. This is illustrated in Figure 2 [2].



(a) (b) (c)

Figure 2: Force distribution in an arch bridge. (a) The load exerts a downward force on the bridge that is translated onto the supports. (b) The substrate exerts an equal but opposite force onto the supports (c) that is transferred to the span of the bridge and works in opposition to the downward force of the load.

The strength of an arch bridge comes from the arch itself. The ability for the bridge to translate the downward force on the span to the supports and the consequent upward force from the substrate to the span is made easier by the gradual change from span the support present in an arch structure. This, in turn, is what gives the bridge strength. It is this and its simplicity that made arch bridges the perfect candidate to base the air bridge design on.

B. Processing Challenges

Lithography presents one of the major processing challenges in fabricating air bridges because it is used to define the shape of the bridge. Since the air bridges being fabricated are based on an arch bridge, it is necessary to develop a resist process that produces a rounded sidewall profile that will define the arch of the air bridge. This is contrary to conventional resist processing that demands high angle straight walled resist profiles. In order to obtain the rounded profiles necessary for air bridge fabrication the first level photoresist, which defines the shape of the support posts, must be rounded by reflowing the resist and this is done though heating.

Heating photoresist may not present problems early on in the process flow, as several bakes are necessary to prepare the resist prior to exposure, but heating necessary for a rounded profile can present problems further in the process. The basic lithography process consists of six main steps.

1. Dehydration Bake & Adhesion Promotion
2. Photoresist Coating
3. Soft Bake – Solvent Removal Bake
4. Exposure – Patterning Resist
5. Develop
6. Hard Bake – Harden Resist

Of particular interest, especially in further process steps are the dehydration bake, soft bake, and hard bake. While these bakes may be necessary to round the resist profile, they also have other adverse effects that could, especially after metal deposition.

The pre-bake also known as the soft bake is the physical process of conversion of a liquid-cast resist into a solid film [3]. This is done by heating the resist to above evaporation point of the casting solvent, but not high enough to degrade the photosensitive chemicals in the photoresist. During this stage of lithography a huge amount of solvent chemistry is out-gassed from the resist. This out-gassing of solvent could prove problematic after deposition of the metal film that is placed on top of the first layer of resist. While most solvents are evaporated during the soft bake some solvents still remain and when baked will continue to out-gas possibly deforming the metal film now covering the first layer of resist. This problem is also of concern for the second level dehydration bake that is done at a much higher temperature than the soft bake. The problem of solvent out-gassing after metal deposition will limit the thermal budget of the process after metal deposition.

In order to leave free standing structures the underlying layer of resist that supports the bridge to the final fabrication step must be easily removed. This is another step where previous bake could prove problematic to the outcome of the entire process. Baking resist at high temperatures invokes a thermochemical reaction in the resist where the resin, sensitizer, and/or solvents present in the film become hardened [4]. This step is critical in conventional resist processing as it prepares the resist for subsequent process steps where the resist acts as a type of masking layer, but is detrimental the air bridge fabrication because it makes removal of resist in the final step more

difficult. Hardening of resist can be a problem in high temperature bakes such as the dehydration and hard bake.

Alignment is another crucial factor in the fabrication process and could present problems of its own. Alignment is critical as improper alignment could lead to a partial or even total collapse of the bridge structure. Second level lithography must be aligned precisely so that the resist masking the metal film and defining the span of the bridge also covers the support posts. If this does not occur part of the supports could be etched away in the subsequent metal etch step weakening the structure. The three layer film stack consisting of the first layer of resist, metal, and second layer of resist could also cause the loss of the alignment marks. With the importance of alignment on the structural strength of the bridges, the loss of alignment keys is an undesirable side effect to the process, and thus methods of maintaining the alignment keys under three film layers is critical to the process.

III. EXPERIMENTAL DESIGN

The goal of this project was to develop and optimize a process for fabricating air bridges using the available toolset at SMFL. In order to do this several key factors in the fabrication process were selected and studied in order to optimize and test the limits of the process. Resist processing is critical in the fabrication of air bridges as it defines the shape of the bridge. This is especially important in the first level lithography where the shape of the resist profile will determine if the air bridge will have an arch shape critical for support or not. The significance of resist processing in the fabrication process developed required the need to look at two candidate resist processes for fabrication. The two resists considered were Shipley 812™ Positive Resist and AZ5214E-IR™ Resist. The Shipley 812™ process is the standard positive tone process used for g-line lithography at SMFL. AZ5214E-IR resist is often employed in image reversal processes and was used as a candidate process to test against the standard process.

Metal deposition technique and metal thickness were other factors studied during process development. Two different metal deposition techniques, evaporation and DC sputtering, were placed under consideration. The conformal coating of sputtering as well as heating that occurs due to the plasma make DC sputtering the perfect candidate for fabricating strong support structures as well giving the resist an extra chance to reflow during metal deposition enhancing the arch of the bridge. On the other hand, excessive heating during sputter deposition could harden the resist further making it more resistant to resist stripping chemistry. Opposite to DC sputtering is evaporation, where the resist is not heated solving the concerns of hardened resist. The nature of evaporation however could affect the conformity of the film, particularly the sidewall coverage. This is because film coverage using evaporation is based on the substrates line of sight to the target. Sidewall coverage is crucial to the structural strength and stability of the air bridge as the metal that covers the resist profile will define the supporting structure of the air bridge. The enhanced rounding effect due to extra heating during sputter deposition will not be present during evaporation.

Several metal film thicknesses were studied as well in order to determine the maximum and minimum metal thickness that the structures could support. Thick metal films could present too much load force on the bridge while thin metal films may not give the bridge enough support to remain standing. Three metal thicknesses were picked to represent the minimum, mean, and maximum metal thicknesses. These thicknesses were 2000Å, 5000Å, and 10000Å. Aluminum was chosen as the metal film due to its wide use at SMFL. Other metal films could be used, but further investigation is needed.

In order to examine the structural strength of the air bridges a mask was designed that would test distance an air bridge could span as well as the width of the bridge. Of particular interest to development was to see if the distance spanned by the bridge was a function of the width of the support posts/bridge. A small experiment was designed into the mask in order to investigate these factors. Four support/bridge width thicknesses were chosen and the mask broken up into four cells. The basic mask design is depicted in Figure 3.

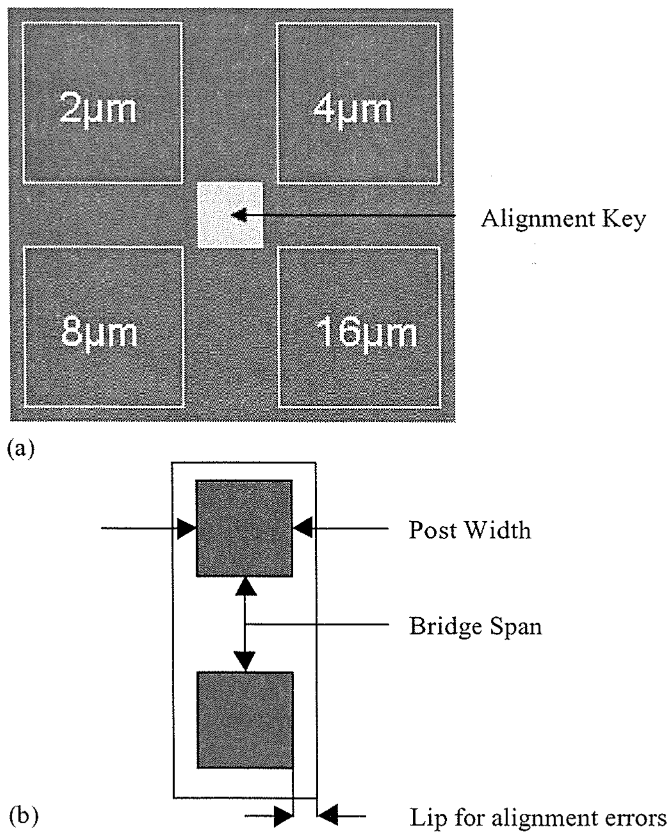


Figure 3: (a) Basic Mask Layout. (b) Bridge Schematic

As seen in Figure 3a, the mask was divided into four different cells each with a different support size/bridge size. With in each cell are five bridges of the same basic design as seen in Figure 3b. The distance between each posts, that defined the span of the bridge was repeated several times to ensure the repeatability of fabricating a bridge at a given span. Each span was in turn incremented in order to examine the structural strength of the bridge as the span increased and to determine at what span distance for a give support post width and metal thickness the bridges start loosing structural integrity. Table 1 shows the initial and final span for each bridge, span increments, and number of support posts per span.

Table 1: Bridge Specifications

	Bridge Num.	Initial Span (μm)	Final Span (μm)	Incre ment (μm)	Posts per Increment
Cell 1 (2μm)	I	2.00	10.00	1.00	20.00
	II	2.00	10.00	1.00	20.00
	III	2.00	10.00	1.00	20.00
	IV	2.00	10.00	1.00	20.00
	V	2.00	10.00	1.00	20.00
Cell 2 (4μm)	I	2.00	9.00	1.00	20.00
	II	9.00	16.00	1.00	20.00
	III	2.00	9.00	1.00	20.00
	IV	9.00	16.00	1.00	20.00
	V	2.00	9.00	1.00	20.00
Cell 3 (8μm)	I	2.00	18.00	2.00	10.00
	II	18.00	28.00	2.00	10.00
	III	2.00	18.00	2.00	10.00
	IV	18.00	28.00	2.00	10.00
	V	2.00	18.00	2.00	10.00
Cell 4 (16μm)	I	2.00	22.00	2.00	5.00
	II	22.00	34.00	2.00	5.00
	III	34.00	44.00	2.00	5.00
	IV	44.00	52.00	2.00	5.00
	V	52.00	60.00	2.00	5.00

Mask was designed using Mentor Graphics IC Station™.

Of final importance to process development was to determine the best resist stripping procedure for removal of resist at the final step of the fabrication process. Two methods were looked at. A wet etch method using acetone followed by a clean in isopropyl alcohol (IPA) and a dry etch process using oxygen plasma were studied. As with the two metal deposition techniques each method presented its own advantages and disadvantages. The wet etch approach using acetone is more gentle than the dry etch method and would present less chance of damaging or deforming the air bridges during the last step of fabrication. However, acetone may not be aggressive enough to remove all of the resist leaving structures that are still partially supported by photoresist. Complete removal of photoresist while leaving the air bridges undamaged were necessary characteristics in this last step of the process.

IV. PROCESS DEVELOPMENT

In order to simplify the fabrication process, a two level lithography process was designed to fabricate the air bridges. The basic fabrication process is begins with the first level lithography in which the support posts of the bridge is imaged into the first layer of photoresist and developed. This process step is one of the most crucial steps in fabrication as this first layer of resist not only defines the support infrastructure of the bridge, but also supports the bridge throughout the entire fabrication process. Metal deposition follows first level lithography in which a film of aluminum is blanket coated on top of the first layer of resist. The bridge span defined by second level lithography. The patterned photoresist is in turn used as an etch mask and aluminum that is not part of the air bridge is etched away. The final step in the fabrication process is to remove the resist layers leaving a free standing aluminum air bridge. The basic process flow is illustrated in Figure 4.

First Level Lithography: Post Definition

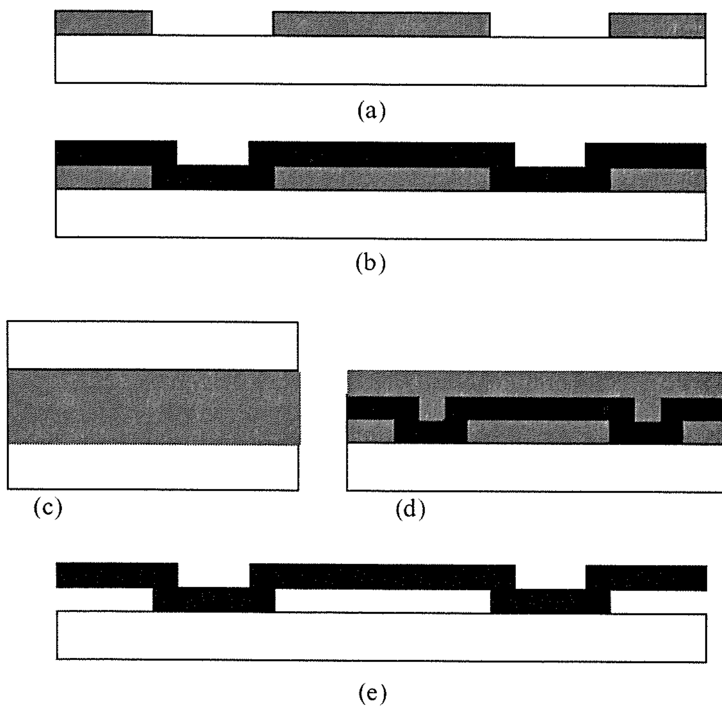


Figure 4 (a) First level lithography. (b) Aluminum deposition. Second level lithography and etch (c) top down view (d) cross-section. (e) Aluminum air bridge.

Substrate Aluminum Photoresist

As stated in the Experimental Design section the factors under investigation were resist process, metal thickness, bridge dimensions, and resist stripping process. In order to optimize the process these factors were thoroughly examined during development. The process steps defined in Figure 4 (a-e) were used in fabrication.

The resist process used for first level lithography was the Shipley 812™ Positive Resist process. Wafers were coated on the SVG88 Coat Track using standard recipe settings. Two wafers were coated for each of the three aluminum film thicknesses studied during this experiment. One wafer would have aluminum deposited via evaporation and the second via DC sputter deposition. Wafers were exposed using the GCA6700 g-line stepper followed by a develop step and hard bake on the SVG88 Develop Track. For first level lithography the standard develop and hard bake recipe was used. The samples were then loaded in their respective deposition tool, the CVC Evaporator for the evaporated sample and the CVC601 for the sputtered sample, and the desired metal thickness was deposited onto the wafer. For evaporation the metal thickness was determined by the Inficon Gauge located on the tool and the deposition stopped when the desired thickness was reached. The desired thickness using sputter deposition was reached by setting the correct deposition time based on the deposition rate for the 2000W aluminum deposition recipe. Deposition rate was found empirically by SMFL Process Engineer. In both cases a glass slide was placed in the deposition chamber with the sample wafers. The glass slides were used to determine the actual thickness of the aluminum film using the Tencor P2 Profilometer.

After aluminum deposition the wafers were then recoated with photoresist for second level lithography. Coating was once again done on the SVG88 Coat Track. Due to concerns of out-gassing from the first layer of photoresist, now underneath the metal, deforming the aluminum film no HMDS prime was used for second level lithography. These concerns were verified when a sample was accidentally ran though the HMDS prime module after metallization destroying the sample. The sample was reclaimed and reprocessed. Standard coat spin speed was used to coat the wafers with Shipley 812™ resist, but a lower soft bake temperature was used to address the concerns of out-gassing. The second level lithography was imaged and developed. No hard bake was used for second level lithography not only to reduce out-gassing, but also prevent further cross-linking and hardening of the underlying layer of photoresist. Wafers were etched in using a wet aluminum etch chemistry set to 50°C. The photoresist was then stripped from the wafers. First set of samples were stripped using acetone followed by an IPA clean. Results, to be discussed further in the Results section, showed that acetone was not aggressive enough to completely remove the resist. A more aggressive process using oxygen plasma was determined to be the best method to remove resist in the final step of fabrication.

One set of samples were set aside to test the effectiveness of the AZ5214E-IR™ Image Reversal process as a second level etch mask. Shipley 812™ was strictly used for the first level lithography due to its effectiveness at achieving the necessary rounded profile. Further investigation could be done to determine the viability of using AZ5214E-IR™ in both positive tone and image reversal for first level lithography.

Samples processed with AZ5214E-IR™ resist for second level lithography were processed using similar process steps as samples prepared using Shipley 812™ for second level lithography. Wafers were coated with Shipley 812™ resist on the SVG88 Coat Track and first level imaged on the GCA6700 g-line stepper. A 5000Å aluminum film was then deposited on the samples. Following the process flow of the previous samples one wafer had aluminum deposited via evaporation and the second via sputter deposition.

The image reversal process diverges from the standard Shipley 812™ process with the second level lithography. HMDS priming was once again not used, but AZ5214E-IR™ resist was manually dispensed onto the wafer at a spin speed of 4200RPM. Soft bake temperature, as in the Shipley 812™ process was set to 105°C. Coating process was done on the SVG88 Coat Track. Wafers were then exposed on the GCA6700 stepper using a dark field mask (opposite that of the mask used in Shipley 812™ processing) followed by the image reversal bake set to 123°C on the Fairweather TPS1010 Hotplate. Wafers were then flood exposed on the Karl Suss MA150 Contact Aligner at an exposure dose of 200mJ/cm^2. Wafers were then developed on the SVG88 Develop Track, with a develop time set to 1:15 min over the standard 0:45 min used in Shipley 812™ processing. No hard bake was used. Aluminum was then etched using wet aluminum etch chemistry at 50°C and resist removed using the Branson 3200 Oxygen Plasma Asher. Initial results showed that out-gassing during the image reversal bake cause the aluminum film to deform. Unfortunately the bake temperature for this step cannot be modified due to the sensitive nature of this particular step in the image reversal process. Results will be discussed more in the following section.

V. RESULTS & ANALYSIS

Samples processed were cleaved for SEM analysis. Analysis was done on the LEO EVO50 SEM.

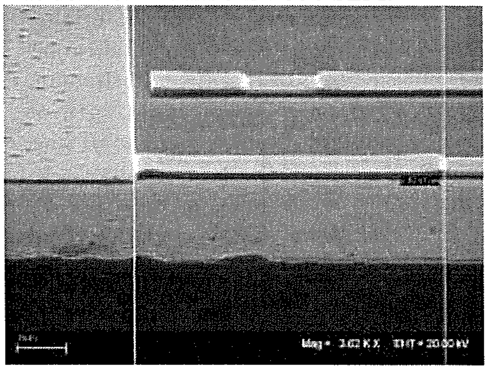


Figure 5: Scanning electron micrograph of an air bridge with post width = 16μm, length = 64μm, and metal thickness = 1μm.

Figure 5 is an SEM micrograph of an air bridge with a width of 16μm and a span of 64μm. The thickness of the aluminum film is approximately 1μm. This sample demonstrates the ability for an aluminum air bridge to support a relatively huge load and remain free standing and is a prime example of the strength of an air bridge.

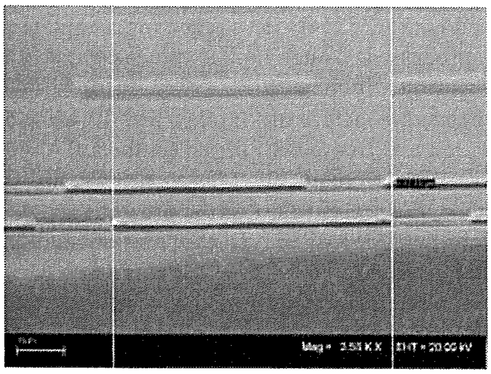


Figure 6: Scanning electron micrograph of an air bridge with post width = 16μm, length = 58μm, and metal thickness = 2000Å

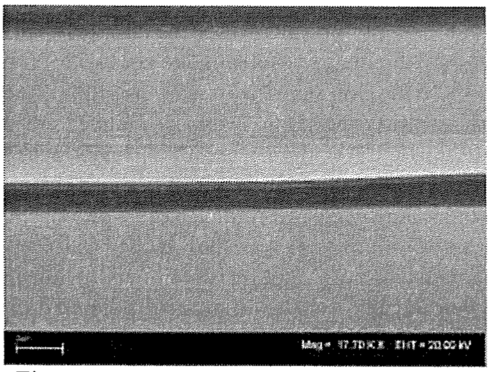


Figure 7: Scanning electron micrograph, center span of air bridge shown in Figure 7. This bridge is suspended, but is bowed at the center.

Figure 6 and 7 show an air bridge with a span of approximately 58μm. This particular air bridge has mask post dimensions of 16μm and has an aluminum film thickness of 2000Å deposited via sputter deposition. Figure 7 is an enlarged picture of the center span of the bridge. There is a slight drop in the height of the span indicating that the bridge is close to the limits of its structural strength, but with a film thickness of only 2000Å and a span of 58000Å (58μm) this is another prime example of the strength of the structure.

Figure 8 shows the results of the rounded resist profile indicating the effectiveness of the Shipley 812™ resist process in fabricating air bridges. Metal was sputtered on this sample also supporting the hypothesis that sputter deposition would be the optimal deposition process for fabrication of air bridges using the developed process. Furthermore, when comparing this image to the micrograph shown in Figure 9 the film thickness at the support in Figure 8 is more conformal and thicker than the support shown in Figure 9 indicating the greater strength of sputtered air bridges over evaporated air bridges, however further samples will need to be fabricated in order to verify this hypothesis.

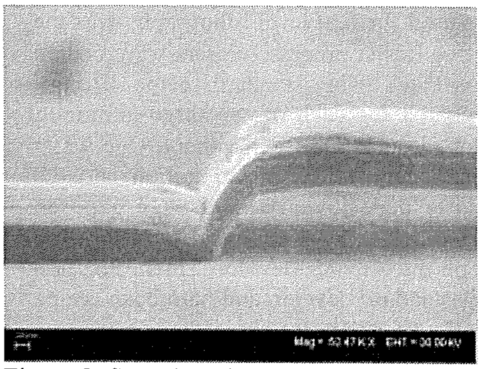


Figure 8: Scanning electron micrograph of the support post of an air bridge. Metal was deposited via sputter deposition. Notice arch profile.

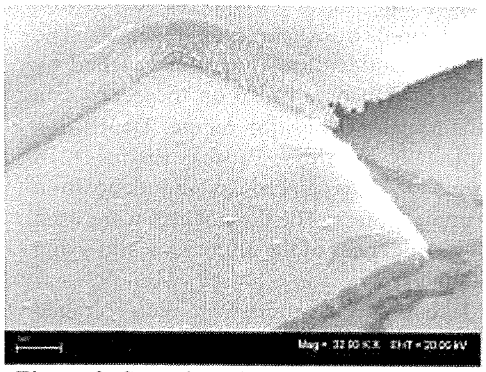


Figure 9: Scanning electron micrograph of the support posts of another air bridge. Metal was deposited via evaporation. Notice the thinning metal at the supports caused by the non-conformal coating that comes with evaporation.

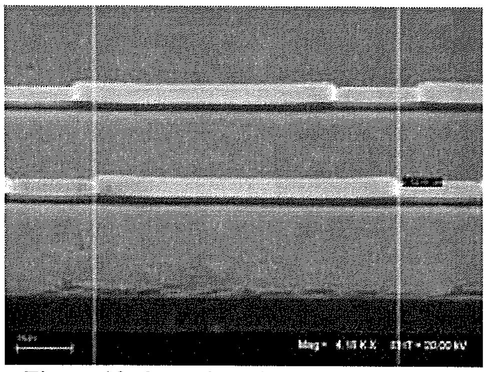


Figure 10: Scanning electron micrograph of an air bridge that was misaligned. Notice the outward projecting lip gives the bridge extra support. This micrograph can be compared to Figure 11 that shows the same bridge but from the other side.

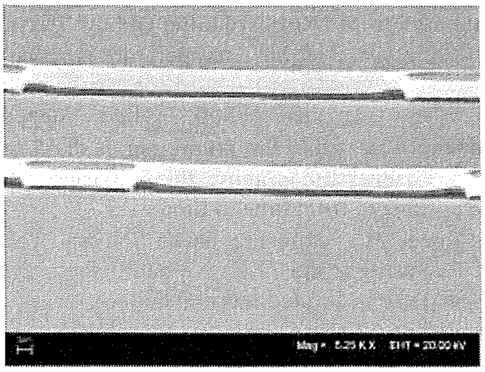


Figure 11: Scanning electron micrograph of an air bridge that was misaligned. Not present in these images, but present in Figure 10 is the outward projecting lip. Notice the partial, but not total collapse of the air bridge.

Figures 10 and 11 are an excellent example of the importance of alignment on the structural integrity of air bridges by showing a misaligned air bridge from both sides. Looking closely at Figure 10 shows a slight outward overhang, relative to the picture, and only a slight dip in the bridge towards the center span. When looking at the same bridge from the other side, as shown in Figure 11, it is observed that the same outward overhang is not present and the bridge is partially, though not fully, collapsed. The overhang present in Figure 10 and not present in Figure 11 is due to a misalignment of the masking resist layer resulting in a bridge with a span slightly off center. The extra support from the overhang on one side of the bridge allows give the bridge extra strength while the lack of an overhang on the other side weakens the structure. Better alignment or a bridge with wider dimensions, compared to the support post width, is needed to evenly distribute to the span giving stronger bridge.

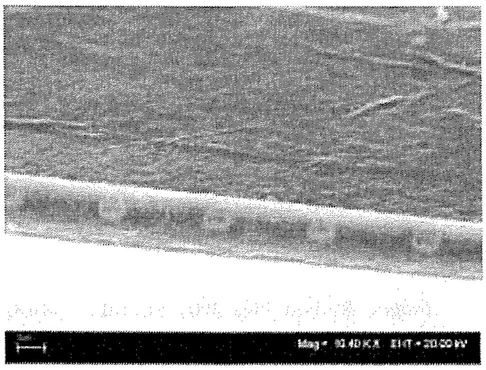


Figure 12: Scanning electron micrograph of an air bridge with incomplete removal of the underlying layer of photoresist. Acetone was used to remove the photoresist.

Figure 12 shows an early sample that used acetone to remove the underlying layer of resist at the end of the fabrication process. Residual resist can clearly be seen underneath the bridge span indicating that acetone was not a viable solution to the resist stripping problem. These micrographs called for the experimentation for more aggressive oxygen plasma etch in order to remove the photoresist at the end of the developed process. Concerns of damaging the air bridges by ashing the wafers at the end of fabrication were wrong as all samples imaged other than that shown in Figure 12 survived the ashing process.

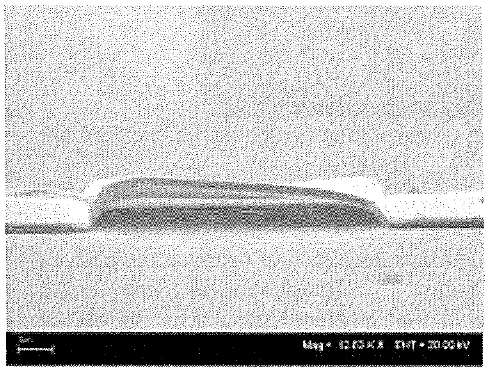


Figure 13: Scanning electron micrograph of an air bridge. Aluminum etch mask, second level lithography was done using the image reversal process. Notice the bulge in one support caused by the out-gassing of solvent from the first layer of resist.

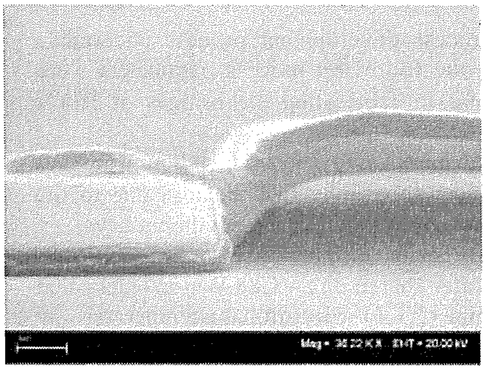


Figure 14: Scanning electron micrograph showing an expanded view of the supports shown in Figure 13.Notice the break in the support metal caused by the bulge.

Figures 13 and 14 show the results of damage to the aluminum film due to out-gassing of solvents after deposition. These images were taken from the image reversal sample where a "high" temperature post exposure bake is needed to cause the image reversal effect in AZ5214E-IR™ resist. Figure 13 shows that out-gassed solvents slightly raised the metal film close to the left support. An expanded view of that support posts show a break in the support producing a weakened structure.

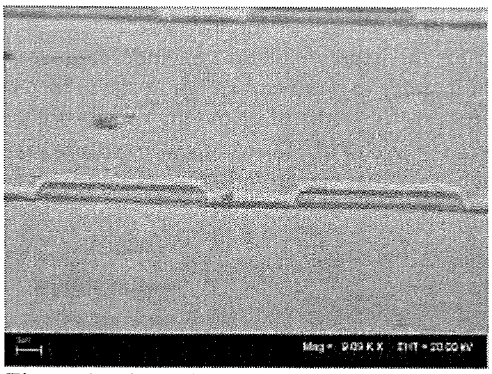


Figure 15: Scanning electron micrograph of the "perfect" air bridge.

Contrary to the images shown in Figures 13 and 14, the image reversal process has appeared to produce the best air bridges as seen in Figure 15. Though several factors could have played a role in the "perfect" fabrication of the air bridges seen in Figure 15, including better alignment, the results from this image indicate the need for further investigation into the use of AZ5214E-IR™ resist for fabrication of air bridges.

VI. CONCLUSIONS

Based on the process development process undertaken during this project the following process parameters were found to be optimal in fabricating air bridges at RIT's SMFL:

1. Etch alignment marks into substrate. Alignment keys for second level lithography may be loss due to the thickness of the films placed above alignment keys.
2. Coat wafer for with Shipley 812™ for 1st Level lithography Wafer coated on SVG88 Wafer Track, coat line using Recipe (1,1,1) with soft bake temperature set to 115°C.
3. 1st Level lithography done on GCA6700 g-line stepper. Exposure time is dependent on starting substrate, but for silicon substrate an exposure time of 0.45 sec is recommended. This exposure time may change the after the next scheduled bulb change on the stepper or as the bulb reaches the end of its usable lifetime.
4. Exposed wafer is developed on the GCA88 Wafer Track, develop line using recipe (1,1) and a hard bake temperature of 125°C.
5. Metal is then deposited on top of patterned wafers. Sputter deposition is the preferred deposition method since it provides a more conformal coat, critical in creating stronger supports, and heating during the deposition sequence could further round the resist profiles (this has not been determined). Limitations of the evaporation tools at SMFL will require sputter deposition for film thicknesses greater than 7000Å.
6. Wafer is prepared for 2nd Level lithography. Wafer is recoated with Shipley 812™ resist using the SVG88 Wafer Track, coat line. Recipe used is (5,1,1), no HMDS prime is used to prevent hardening and out-gassing of the first layer of resist. Soft bake temperature is reduced to 105°C.
7. Exposure is done on GCA6700 g-line stepper. Recommended exposure time for aluminum is 0.45 sec though, as with 1st level lithography, this exposure time may need to be optimized from time to time.
8. Wafer is developed after exposure using SVG88 Wafer Track, develop line using recipe (1,2). No hard bake is used in this develop step due to limited thermal budget.
9. Wafer is then etched using Aluminum Wet Etch Bench with bath temperature set to 50°C. For smaller bridge widths an anisotropic etch using the LAM4600 may be needed. This was not tested because the tool was down, but indications from process development showed that undercutting from the isotropic wet etch process caused the loss of the 2μm width bridges in a majority of the fabricated samples.
10. Resist is removed using the Branson 3200 Oxygen Plasma Asher. Recipe used was the 4" Hard Ash Recipe. Acetone proved to a bad process for resist stripping, but may be a viable solution using ultrasonic agitation. This will have to be investigated further.

A baseline process was developed for fabricating air bridges using SMFL's g-line lithography tools. The process proved to be a robust process for fabricating air bridges producing air bridges that spanned distances greater than 50μm with both thin and thick metal films. Further optimization of the process could be done by investigating the use of AZ5214E-IR in both image reversal and positive tone as initial results show that this resist process has promise in fabricating air bridges. Other metals can also be used in air bridge fabrication and require further study before implementing into the developed process.

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