The Effect of Exposure Mode on Feature Resolution and Film Thickness for Thick (>10 um) BCB

J. Parke, A. Gupta, J. Mason, K. Renaldo
Northrop Grumman Electronic Systems, 1212 Winterson Rd. Linthicum, MD 21090 USA
Phone: 410-765-4488 email: justin.parke@ngc.com

Benzocyclobutene (BCB) is a low-k, spin-on dielectric with applications in GaAs and GaN MMIC processing as a scratch protection layer, an inter-level dielectric (ILD) layer for additional metal levels, and the fabrication of high performance passive components, low-loss balun structures and low-loss transmission lines.[1] The BCB thickness impacts the performance of the passive components (through parasitic capacitance), and the coupling of the baluns, thus a thick (10-15µm) film is desirable. However, thick BCB poses several process challenges related to thickness uniformity, feature resolution and size control, pattern density variation, continuity of through-BCB metal connections, and surface topology.[2,3]

A typical photoimageable BCB process flow includes spinning and baking the BCB film, exposing the film with a contact aligner or stepper, and developing the pattern. The film must be cured for polymerization followed by a plasma descum step to remove any developer and/or BCB film residue from the opened areas. The thickness of the film decreases after develop, after cure, and again after plasma descum.[4]

In order to optimize the minimum feature size using a contact aligner for standard photo-resists, hard contact exposure is typically preferred over proximity exposure mode. In this paper we present results of hard contact versus proximity exposure for thick BCB.

Experiments were conducted to compare the two exposure modes. The results were analyzed in terms of feature resolution and film thickness. Contrary to expectations, it was found that the proximity mode provided better feature resolution as compared to hard contact. Furthermore, hard contact led to less film thickness loss during develop.

Figures 1 and 2 show SEM wafer maps of BCB openings on wafers exposed using hard contact and proximity modes respectively. Figure 1, from a wafer exposed using hard contact, typifies the inability of this method to fully open the BCB vias in a consistent and repeatable manner. The degree of inconsistency was found to vary across a wafer and from wafer to wafer within the same lot. Figure 2 is a typical result of proximity exposure which consistently yielded well defined openings. In these figures, the open regions are 50µm x 50µm on the mask plate.

Figure 3 shows average thickness change of the BCB film from coat to cure for the two exposure modes with ~1 µm greater loss for proximity compared to hard contact. Figure 4 indicates that exposure dose and the density of features on the BCB mask also have an impact on the film loss during develop and cure, with lower density and lower exposure dose both yielding greater thickness loss. These plots include data from both hard contact and proximity exposures.

Further experiments were done to investigate the effect of ultra-low density BCB masks on BCB loss and loading effects during the plasma descum step. The results are summarized in figure 5 which indicates that for very low density masks a large thickness change is unavoidable. Further details of experiments and results will be presented at the conference.

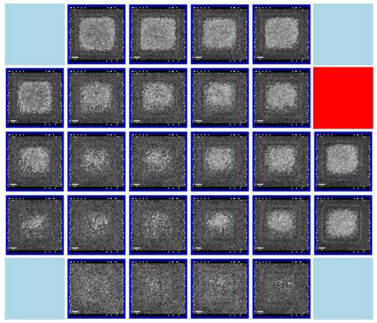

Fig. 1. SEM wafer map of BCB openings formed using hard contact exposure mode

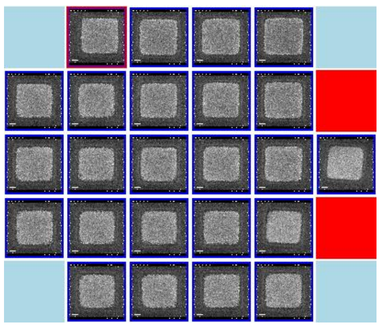

Fig. 2. SEM wafer map of BCB openings formed using proximity exposure mode

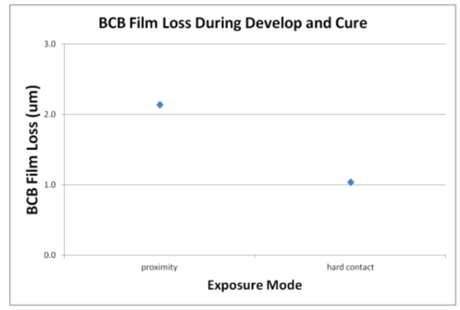

Figure 3. Thickness loss of BCB film for proximity and hard contact exposure modes during develop and cure

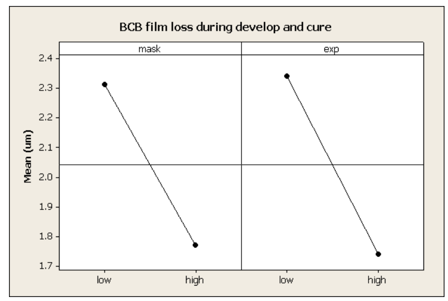

Figure 4. Effects of density of mask features and exposure dose on BCB film loss during develop and cure. Data from hard contact and proximity exposure is averaged.

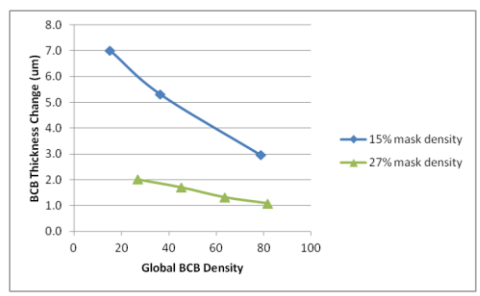

Fig. 5. Change in BCB thickness after etching for different mask densities and loading effects

---

[1] E.J. Stewart, R.G. Freitag, J.S. Mason, M.J. Walker, H.G. Henry, and K.M. Renaldo, *"Low-Loss Metal-on-BCB Technology for Next Generation GaN MMICs"*, 2012 CS MANTECH Technical Digest, pp. 207-210, April 2012

[2] J. Brown, A. Zhou, J. Campbell, A. Ketterson, *"Optimization and Characterization of a Photo Definable BCB for HV3S and HVHBT Technologies",* 2011 CS MANTECH Technical Digest, pp. 139-142, May 2011

[3] T. Dungan, *"Characterization of BCB Planarization of Isolated and Dense Features in a High Topography HBT Process"*, 2011 CS MANTECH Technical Digest, pp. 143-146, May 2011

[4] Dow Chemical Product Literature