

Temperature control of multiple wafers during etching of 2" Sapphire wafers for Patterned Sapphire Substrates (PSS)

Dr Mark Dineen¹ and Dr Zhong Ren¹

¹Oxford Instruments Plasma Technology, Yatton, Bristol, UK

Introduction

In recent years GaN grown on sapphire has become a standard method of producing High Brightness Light Emitting Diodes. There is great interest in patterning the sapphire substrate as a pre-growth step as it offers; improvements in quality in the GaN that is grown on top and also gives higher light extraction from the finished device. However, sapphire is a very stable material, its melting point is 2054° C [1], making it difficult to plasma etch. In order to etch the material combinations of Cl₂, BCl₃, Ar and HBr are commonly used [2,3,4] with higher etch rates achieved at higher plasma source powers. However this increases the heat load on the sample therefore, in order to use Photoresist (PR) as a mask and maintain a high etch rate, it is necessary to actively cool the wafer sample. With Patterned Sapphire Substrate (PSS) etching for HBLEED devices they are commonly manufactured on 2" wafers so, to significantly reduce costs, it is desirable to process as many wafers in one run as possible.



Figure 1 Oxford Instruments System133-ICP380

Experimental

The system used for the etching trials was a Oxford Instruments Plasma Technology System133-ICP380, as shown in figure 1. This is a plasma etch system configured with; an Inductively Coupled Plasma source enabling high density plasma etching, a chiller unit attached to the lower electrode capable of achieving -20°C and equipment to maintain a pressure of He behind any sample placed on the lower electrode. A fluoro optic probe was used to measure the temperature of items under plasma processing conditions. Twelve 2" sapphire samples were placed in the multi-wafer carrier as shown in figure 2. An Ar plasma was used for the temperature tests with the temperature of the wafers measured under varying process parameters.

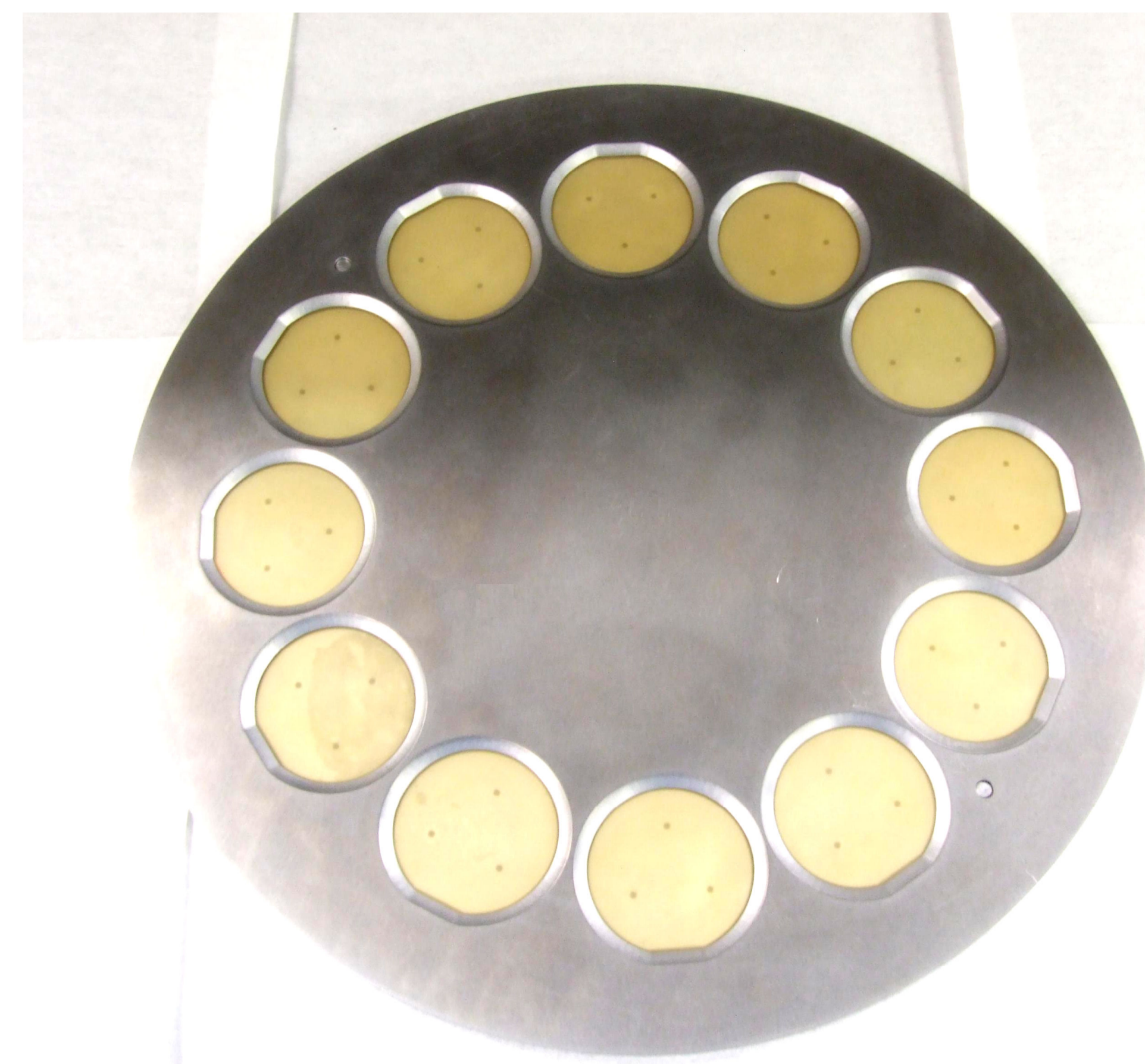


Figure 2 Sapphire wafers loaded into carrier assembly

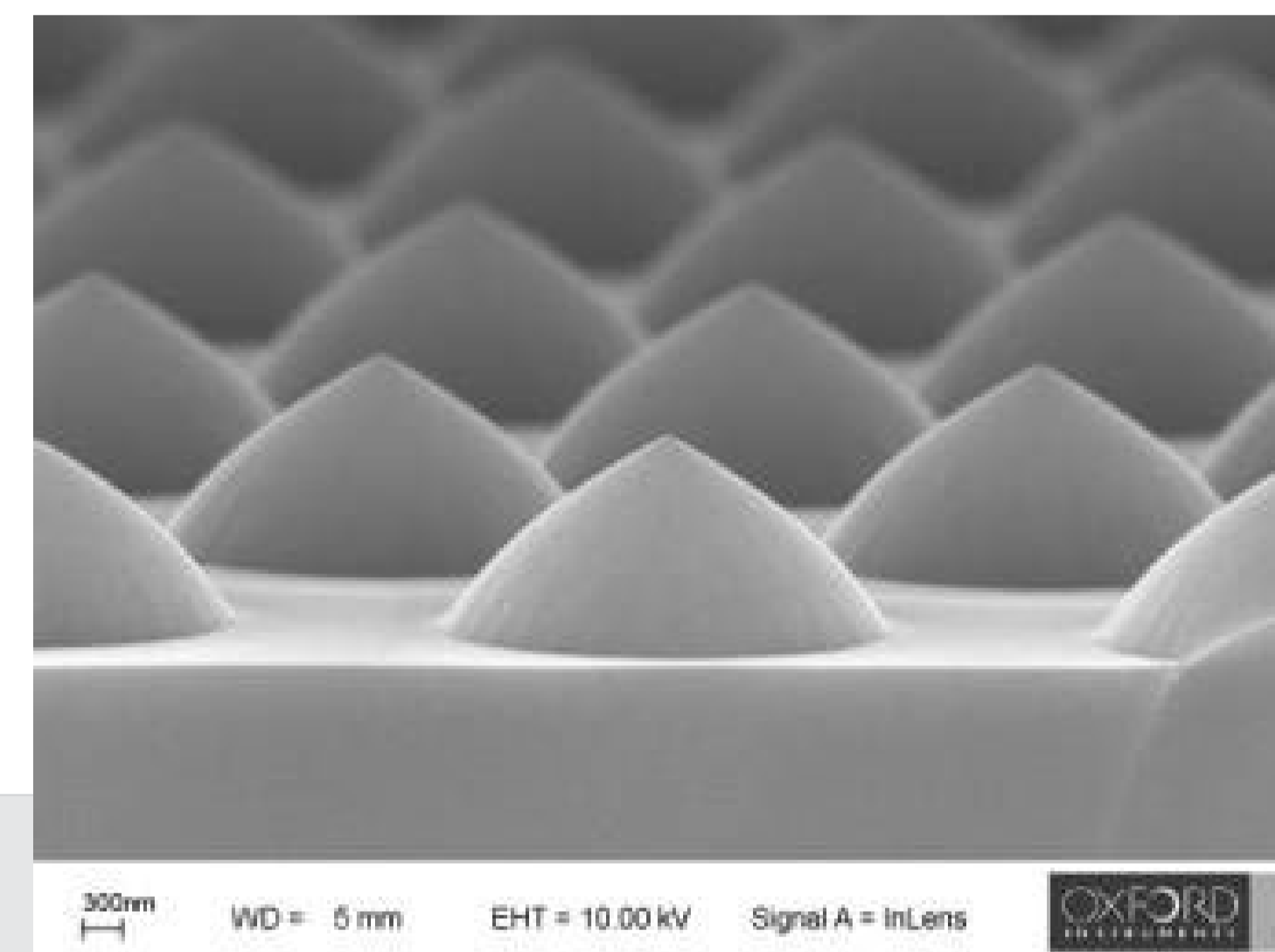


Figure 6 Feature etched into Sapphire substrate no PR mask remains

Results and discussion

The importance of He backside cooling is shown in figure 3. It is shown that with He backside pressure the sample temperature reaches a steady state of approximately 50°C within 10 minutes but without He the sample temperature continues to rise reaching >200°C within that time.

The effect of RF Electrode power and process pressure are shown in figures 4 and 5. The temperature of the wafer is elevated at the higher power, this is expected as higher power results in increased plasma density and higher self bias on the lower electrode.

The wafer temperature varies with changing pressure because of opposing effects of energy loss collisions within the plasma versus an increase in ion flux on the sample.

A BCl₃ based recipe was used to etch twelve 2" wafers with a PR mask in a single batch giving the following results:

- **Etch rate:** 50nm/min
- **Uniformity wafer to wafer:** <+/-5%
- **Selectivity to PR:** >0.6:1

A typical etch feature is shown in figure 6.

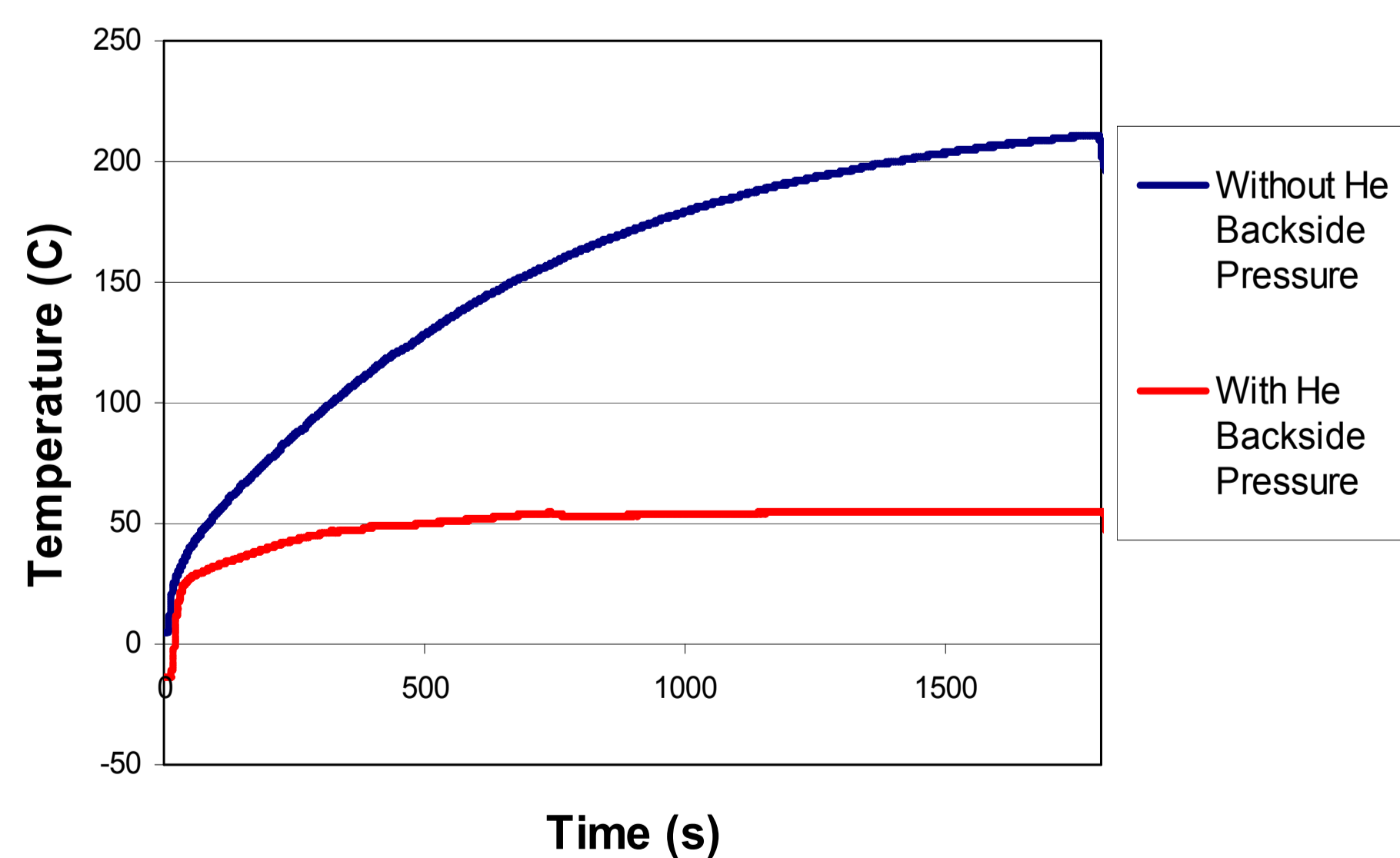


Figure 3 The effect of He backside pressure on the cooling efficiency during processing

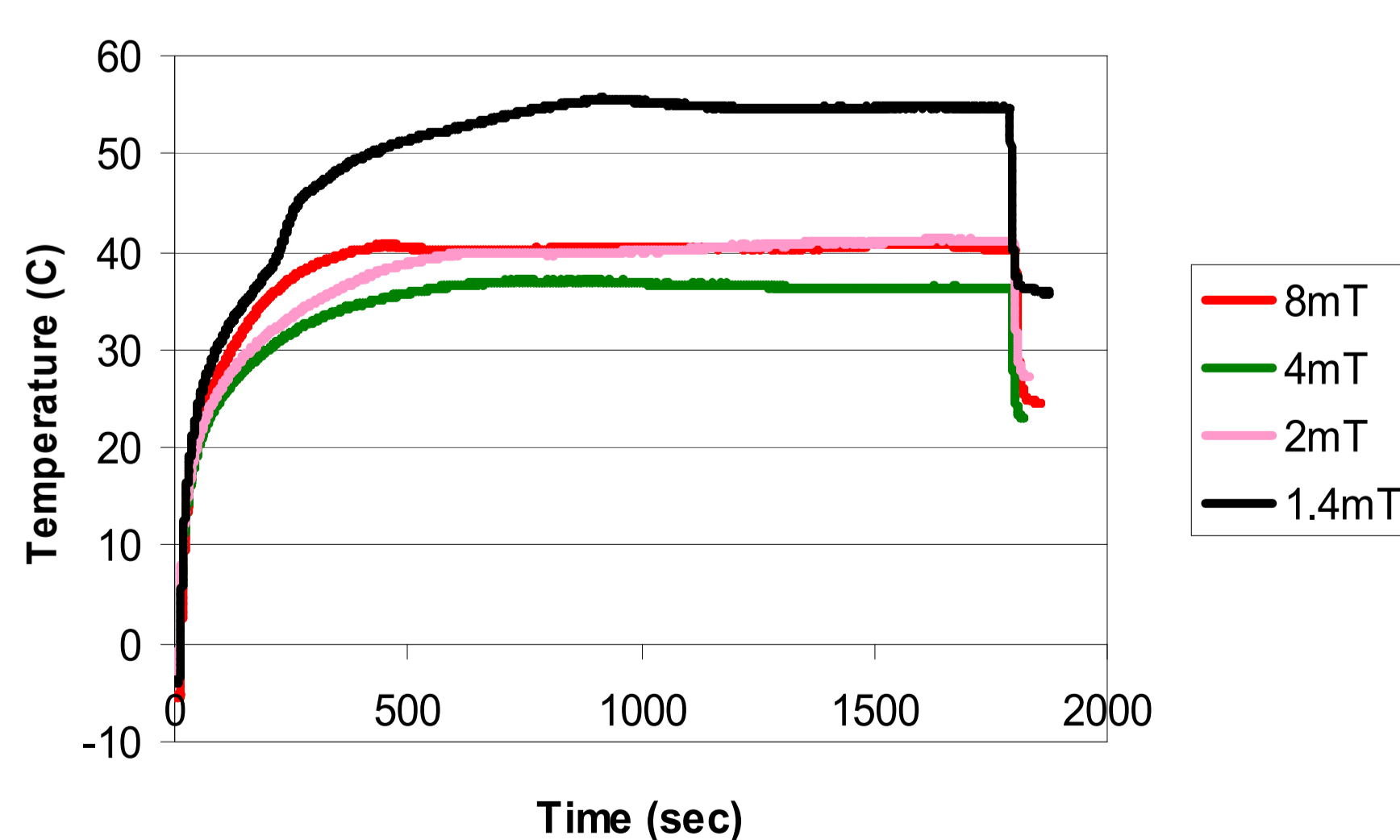


Figure 4 The effect of RF electrode power on the wafer temperature

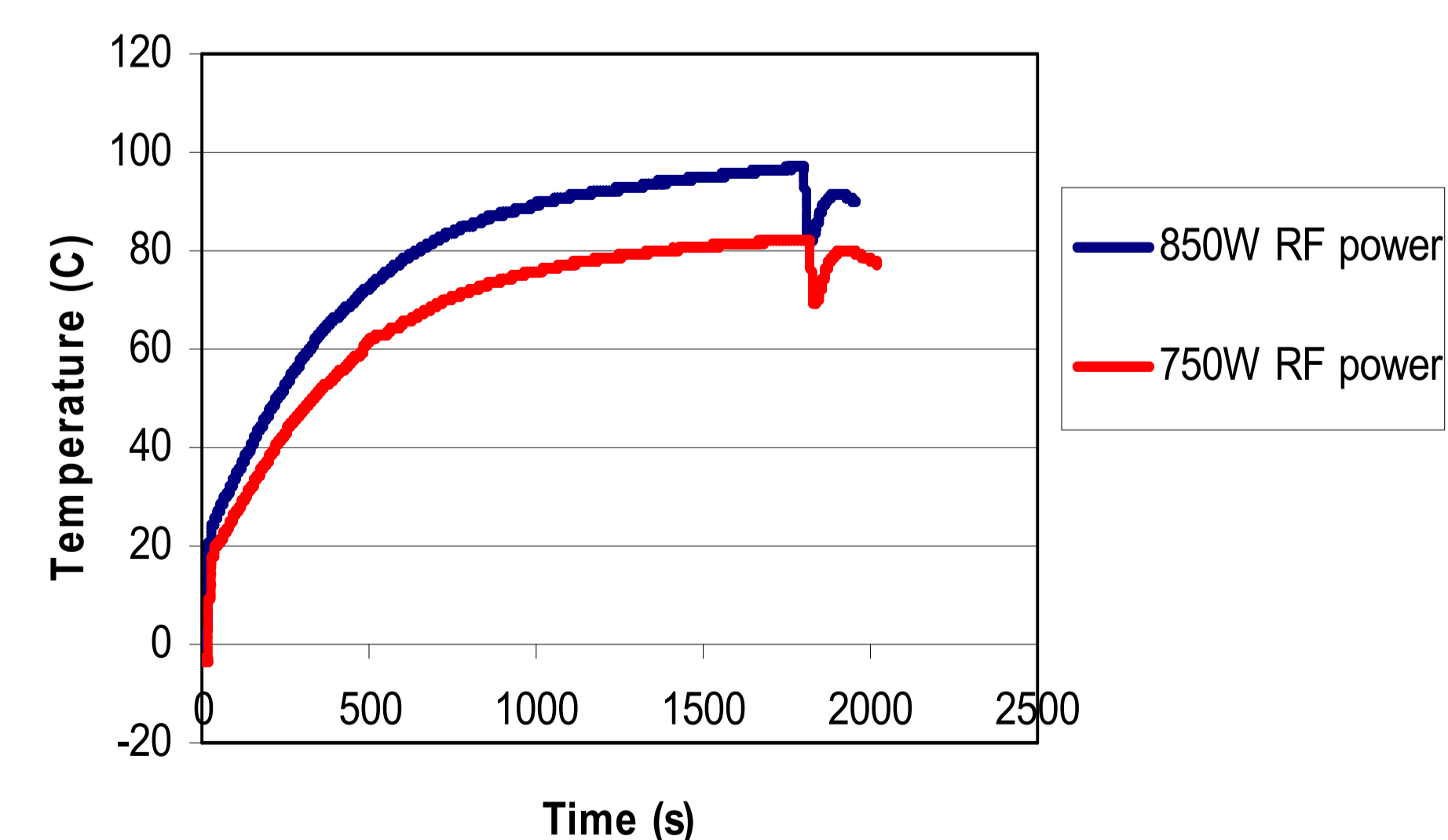


Figure 5 The effect of process pressure on the wafer temperature

References

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- [4] Seong-Mo Koo, Dong-Pyo Kim, Kyoung-Tae Kim and Chang-Il Kim, Materials Science and Engineering B, Volume 118, Issues 1-3, 25 April 2005, Pages 201-204, EMRS 2004, Symposium D: Functional Oxides for Advanced Semiconductor Technologies