Surface Channel Diamond Field Effect Transistors: Recent Progress and Future Challenges

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Diamond has often been described as the ultimate electronic material due to its outstanding physical properties such as unrivalled thermal conductivity, extremely large electronic bandgap and very high charge carrier mobility (Fig. 1) [1]. Such extreme properties find application in a high power / high frequency transistor technology for operation in extreme environmental conditions e.g. in space based electronics or terrestrial systems required to operate in adverse temperature conditions.

Although currently limited by stability issues, the hydrogen-terminated diamond surface provides a method of producing high performance field effect transistors (FETs) [2]. In particular, excellent high frequency FET operation utilising hydrogenated diamond has been demonstrated by several groups [3-6]. Further investigation into the intrinsic performance limitations and device operation as gate length is reduced however is essential in unveiling the potential of this material system as a viable and competitive high power and high frequency device technology.

Recent work at the University of Glasgow has focussed on the scaling of hydrogenated diamond FETs down to device dimensions previously unexplored to gain insight into the intrinsic operation and performance limitations of this unique material system [2]. This had led to the demonstration of the shortest gate length and highest frequency performance diamond FET yet reported.

Typical 50 nm gate length FET output characteristics from this work are presented in Fig. 2. Performance figures include a maximum drain current I_{dmax} ~ 300 mA/mm and a peak extrinsic transconductance g_m ~ 100 mS/mm. At a reduced gate length of 50 nm, efficient control of the drain current is still maintained and a minimum I_{on}/I_{off} of ~ 1.5 $x10^4$ extracted. S-parameter extraction and RF characterisation yielded performance figures of f_T = 53 GHz and f_{max} = 27 GHz for these 50 nm devices (Fig. 3).

Although diamond FETs have demonstrated excellent high frequency performance potential, high power operation remains limited by the lack of a suitably stable conduction mechanism in diamond. This stems from the current dependency upon the presence of atmospheric adsorbates on the hydrogen-terminated diamond surface to form the conductive channel used in electronic devices. Recent work however has highlighted a range of potentially suitable "surface acceptors" to encapsulate the h-diamond surface with to promote greater stability of operation [7,8]. Effort must now focus on the investigation and implementation of these processes to address the current performance limitations of diamond FET technology.

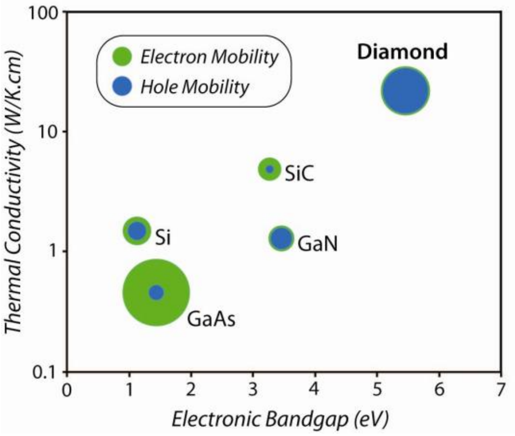

Fig. 1. Common device semiconductor material properties

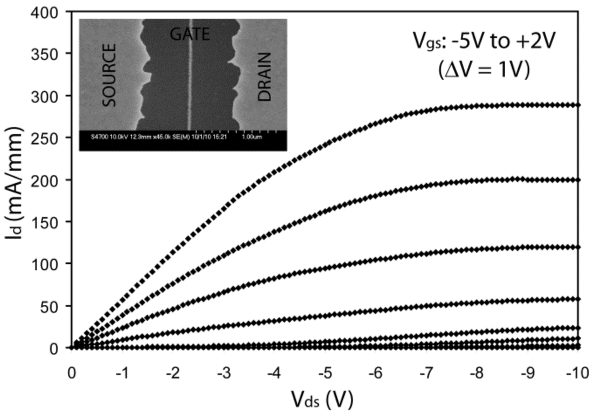

Fig. 2. Output characteristics of 50nm gate length diamond FET. (Inset – SEM of measured device)

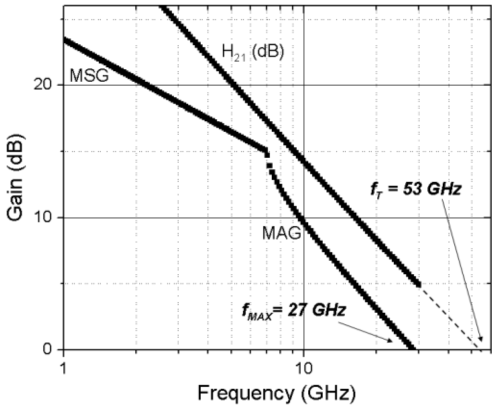

Fig. 3. 50 nm RF performance

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