Contact Resistance Limits of Ohmic Contacts to Thin Semiconductor Channels

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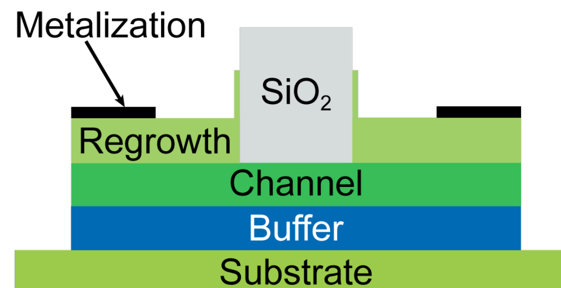
Introduction:

- InGaAs MOSFETs need contact resistance of < 10 Ω µm for L_g=L_c=*20 nm*[1]
- We show epitaxially regrown source-drain contacts as low as 65 Ω µm to thin channels and 12.5 Ω µm to thick channels
- *There is a minimum measurable contact resistance for a given* n_s *(channel thickness)*
- Limit independent of material system & should not impact transistor performance

Our Approach:

- Homoepitaxial regrowth → best regrowth-channel contact resistance
- InAs → best metal-regrowth contact resistance[2]
- Demonstrate existence of relationship between channel n_s and contact resistance extraction



[1] *M. J. W. Rodwell et al, IPRM (2008)*

[2] *A. Baraskar et al, IPRM (2010).*

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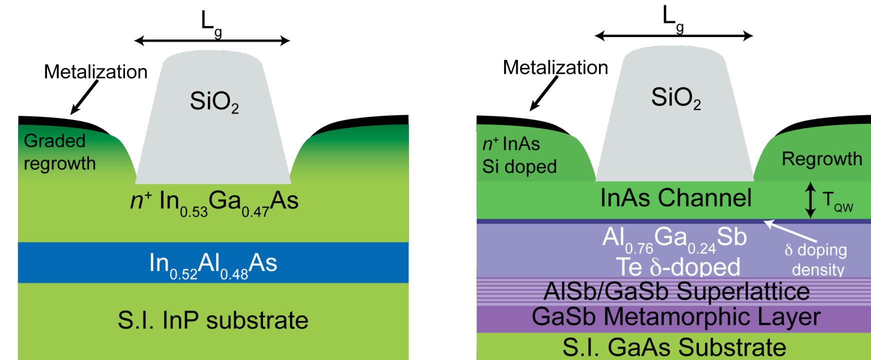
Experimental Details:

- Channels of varying n_s grown by MBE
  - 15 nm InAs and 100 nm n^+ InGaAs channel
- Homoepitaxial regrowth by MBE
  - n^+ InAs and graded n^+ InGaAs to n^+ InAs
- TLM for contact resistance measurement



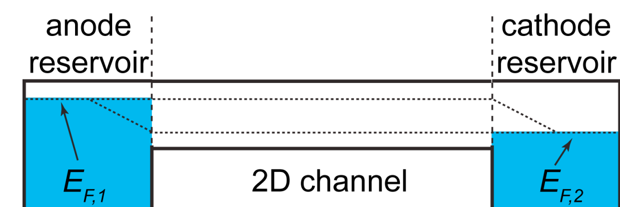
Experimental Results

Thickness	Regrowth	$R_{RG\text{-}C}$ ($\Omega\ \mu m$)	$R_{M\text{-}RG}$ ($\Omega\ \mu m$)
15 nm InAs	*n^+ InAs*	~ 65 (130 R_{S+D})	~ 3.0
100 nm n^+ $In_{0.53}Ga_{0.47}As$	*Graded from n^+ $In_{0.53}Ga_{0.47}As$ to n^+ InAs*	~ 12.5	~ 3.0

Theory Results:

- 15 nm InAs device: theoretical min. R_C=80 $\Omega\ \mu m$
- Our regrowth is within a factor of 2 of this limit
- 2-D generalization from Landauer:*

$$G = \frac{q^2 2^{1/2}}{\hbar \pi^{3/2}} \sum_i n_{s,i}^{1/2}$$



*R. Landauer, IBM J. Res. Dev. **1**, 223 (1957).

Conclusions:

- There is a minimum measurable contact resistance from a TLM structure
- $R_{C,min}$ is a function of channel sheet carrier density
- Limit applies to all materials systems not just $In_xGa_{1-x}As$
- Minimum resistance is ***not*** an additional parasitic resistance if integrated into an FET
- n^+ InAs regrowth $R_S+R_D=130\ \Omega\ \mu m$ is within a factor of 2 of theoretical $80\ \Omega\ \mu m$
- Graded regrowth not limited by n_s shows $R_S=R_D=12.4\ \Omega\ \mu m$

TLM extraction of R_C on channels with small n_s not representative of contact resistance

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