InSb etch development update

Devin Brown
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EBL pattern definition in resist at 2 nA

- pattern in ZEP520 resist on InSb
- initially tried 2 nA beam current as this is our default setting
- semi-circles are not well formed (above)
- CAD definition, semi-circles, radius = 120 nm, hexagonal array pitch = 600 nm
EBL pattern definition in resist at 600 pA

- pattern in ZEP520 resist on InSb
- lowering beam current to 600 pA from 2 nA decreases beam diameter and improves resolution
- pattern quality is better
- CAD definition, semi-circles, radius = 120 nm, hexagonal array pitch = 600 nm
InSb ICP etching in literature

• 4 main papers on InSb ICP etching in literature
  – Diniz, et. al. 1998, “Inductively coupled plasma etching of In-based compound semiconductors in CH4/H2/Ar”
  – Hahn, et. al. 1999, “Effect of inert gas additive species on Cl high density plasma etching of compound semiconductors Part II. InP, InSb, InGaP and InGaAs”
  – Hahn, et. al. 2000, “Inductively Coupled Plasma Etching in ICI- and IBr-Based Chemistries. Part II: InP, InSb, InGaP, and InGaAs”
  – Zhang, et. al. 2009, “Inductively coupled plasma-reactive ion etching of InSb using CH4/H2 /Ar plasma”
InSb ICP etching in literature

- In general, two chemistries reported:
  - Cl/Ar, where InCl$_x$ is the volatile product
  - CH$_4$/H$_2$, where SbH$_3$ is the volatile product
- Most papers report that InSb etching in general produces high surface roughness (< 20 nm RMS) and may only be appropriate for through/via etching.
- However, Zhang et al. reports low roughness with CH$_4$/H$_2$ and RIE like conditions.
• initially tried an existing Cl recipe for InSb
• result was not good, semi circles turned into crescents and etch was very shallow

Plasma Therm ICP recipe = TJB_INS
press = 5 mTorr
Cl2 = 20 sccm
H2 = 15 sccm
Ar = 5 sccm
RF2 coil = 600 W
RF1 RIE = 200 W
attempt with CH4/H2

- attempted one of the promising conditions from Zhang, 2009
- however, etch result pretty rough for 120 nm features
- Zhang paper only shows ~5 um features, perhaps not representative for nanoscale

tool = STS SOE
recipe = DKB_INSB
Ar = 5 sccm
CH4 = 15 sccm
H2 = 50 sccm
ICP = 600 W
RIE = 150 W
press = 7 mTorr
etching of Silicon as reference

- above is the etch result with the same CAD pattern and EBL on silicon (post resist strip) with a known good etch recipe
- because silicon etch result is good, we know that EBL lithography is good, and bad result in InSb is due to etch recipe

tool = Plasma Therm ICP, left chamber
recipe = DKB_SI
16 sccm Cl2
4 sccm Ar
press = 5 mTorr
50 W RIE
200 W coil
second Cl2 attempt

first recipe attempt
Plasma Therm ICP
recipe = TJB_INSIB
press = 5 mTorr
Cl2 = 20 sccm
H2 = 15 sccm
Ar = 5 sccm
RF2 coil = 600 W
RF1 RIE = 200 W

second recipe attempt
Plasma Therm ICP
recipe = DKB_SI
press = 5 mTorr
Cl2 = 16 sccm
Ar = 4 sccm
RF2 coil = 200 W
RF1 RIE = 50 W

- second recipe attempt drops H2 (Hahn, 1999 does not use H2, but attempts Ar, He, and Xe), H2 may be hindering Cl and producing CH by-products as it reacts with resist
- lowering coil and RIE/platen powers to more RIE like conditions (reported by Zhang, 2009 to have lower roughness)
- result with second recipe does look better/deeper than first Cl2 attempt, but there is roughness
second CH4 attempt

**first recipe attempt**
- tool = STS SOE
- recipe = DKB_INSB
- press = 7 mTorr
- CH4 = 15 sccm
- H2 = 50 sccm
- Ar = 5 sccm
- ICP = 600 W
- RIE = 150 W

**second recipe attempt**
- tool = STS SOE
- recipe = DKB_INSB (#2)
- press = 7 mTorr
- CH4 = 15 sccm
- H2 = 50 sccm
- Ar = 5 sccm
- ICP = 600 W
- RIE = 50 W

- try lowering RIE power from 150 W to 50 W per data from Zhang, 2009
- however, result still looks rough, actually worse so