機能レイヤ分離設計による SOI RF-MEMS 受動素子に関する研究

A Study on SOI RF-MEMS Passive Devices by Functional Layer-wise Design Method

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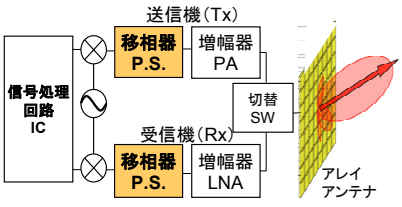
A novel design of switched-line RF-MEMS (radio frequency micro electro mechanical systems) phase-shifter for the X-Ku band (8 ~ 18 GHz) has been successfully developed by monolithically integrating electrostatic MEMS actuators with movable coplanar waveguides made of single crystalline silicon. MEMS and RF waveguides designs have been performed with minimum geometrical conflicts thanks to the layer-wise functional allocation method, where double surfaces of SOI (silicon on insulator) wafer are used. We have successfully demonstrated the design principle on a 1-bit phase-shifter of 22.5 degrees at 12 ~ 13 GHz and obtained insertion loss of 1.6 ~ 1.9 dB/bit, return loss of -9 ~ -13 dB, and isolation of -40 dB by the electrostatic operation under 40 V.

Introduction

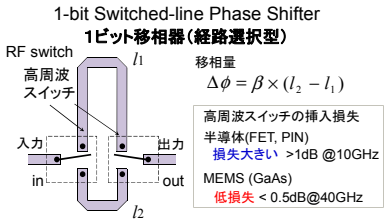
Up（上り）14GHz
Down（下り）12GHz

人口衛星と地上移動体（車、飛行機、船）との無線通信には、電波の指向性（向きと強度）を電子制御できるフェイズドアレイアンテナが有用とされています。

⇨ しかし、現在のフェイズドアレイアンテナは内部の移相器による信号損失が大きく、システムが大型・高価格となっています。



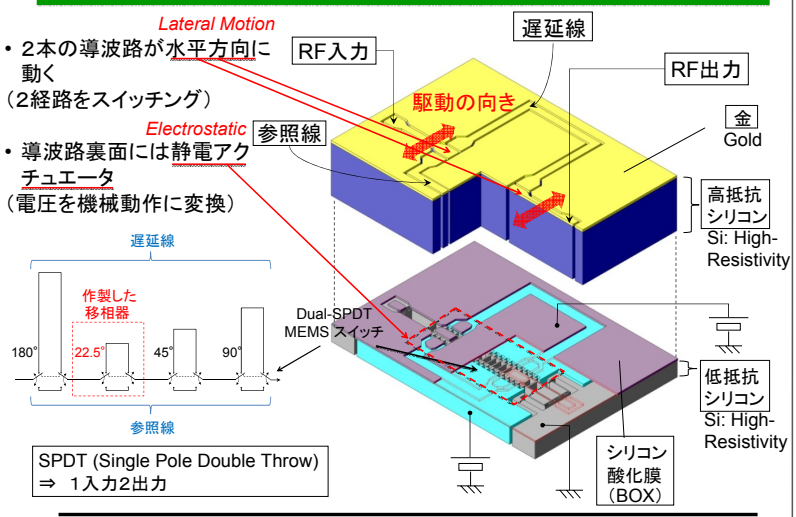
フェイズドアレイアンテナ システム
Phased Array Antenna System



低損失のMEMS高周波スイッチで移相器の特性を改善する

① 材料：シリコン Silicon Sub. ⇒低コスト low cost
② 12-14GHzで低損失 Low insertion loss ⇒増幅器へ低負荷 low power
③ スイッチと導波路を一体化 Monolithic with SW and WG ⇒小型化 small size

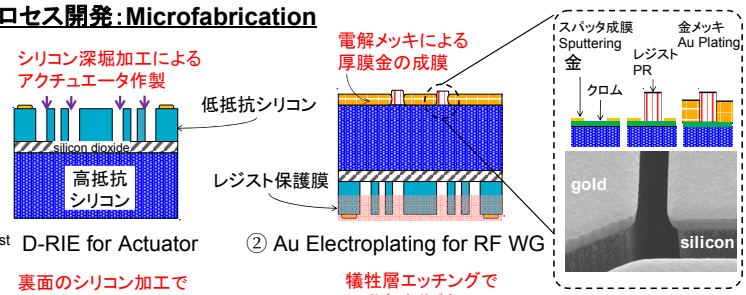
Experimental setup



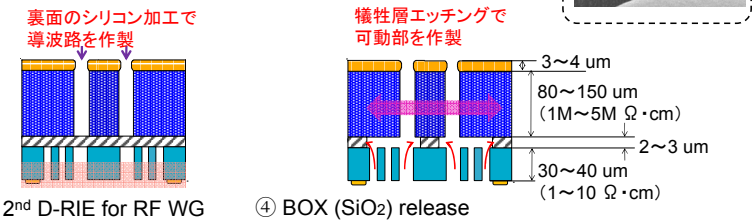
SPDT (Single Pole Double Throw)
⇒ 1入力2出力

Result

プロセス開発：Microfabrication

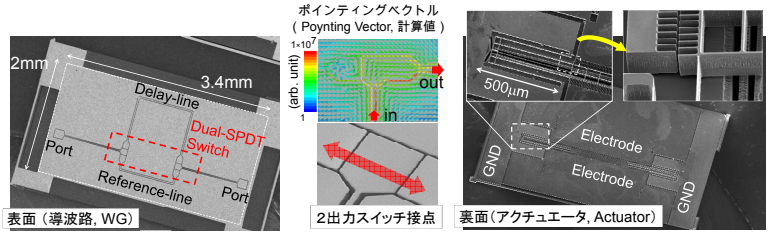


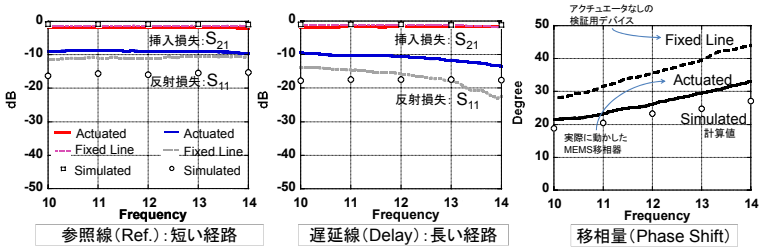
① 1st D-RIE for Actuator
② Au Electroplating for RF WG



③ 2nd D-RIE for RF WG
④ BOX (SiO_2) release

特性評価：Measurement & Simulation





Conclusion

We have developed a monolithically integrated RF-MEMS phase-shifter for a 12 GHz application by improving the previously reported dual SPDT RF-MEMS switch. SOI substrate was used to accommodate the electrostatic actuation mechanism in the 30 μm-thick silicon layer and to allocate mechanically movable waveguides on the 100 μm-thick substrate; electroplating of 4 μm thick gold was applied onto the waveguide surface to lower the microwave insertion loss.

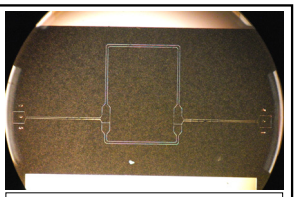


Photo of Monolithic Phase Shifter

At the same time, high resistance silicon was used for the handle wafer of the SOI to minimize dielectric loss. Electrostatic operation at 40 V was successfully demonstrated to present a 1-bit phase shifter of 22.5 degrees at 12 ~ 13 GHz, insertion loss of 1.6 ~ 1.9 dB/bit, return loss of -9 ~-13 dB, and isolation of less than -40 dB.

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