Chapter 6

Conclusion and Future Study

6-1. Conclusion

This dissertation has presented two kinds of microelectronic antennas and a novel structure to suppress the back-lobe reflected power of a short leaky-wave antenna. These designs were achieved by roughly estimating the physical dimensions of the antennas and circuits by theoretical equations at first, and then modifying its electric properties by theoretical equations first, and then modifying its electric properties by simulation tools.

A microelectromechanical dual band monopole antenna has been fabricated on a parylene substrate. Since parylene is a flexible polymer film, it can be coated on various substrates or even peeled off and used as a thin flexible substrate by itself. Hence, parylene can serve as a substrate not only for an antenna but also for other kinds of RF devices due to its excellent physical, mechanical and chemical properties such as low dielectric constant, high resistivity, and inertness to chemicals. Generally, such design has the benefit that the RF antennas can be used with high flexibility, high performance and simple fabrication process. The measured results of the fabricated antenna agree very well with the simulated results, and this demonstrates another advantage: the characteristics of this type of antenna can be well-designed easily and accurately predicted before fabrication.

A 3-D MEMS compact monopole antenna for WLAN application has been realized by interconnection technology which consists of through hole drilling and copper filling. It was fabricated in the form of a folded meander line on both the upper and lower surfaces of the substrate in order to achieve smaller size and wider bandwidth compared to traditional microstrip antenna. Measured performances of the fabricated antenna are in good agreement to the designed values in terms of operating frequency at 2.45 GHz and bandwidth of 190 MHz. Moreover, the resonant frequency can be tuned by its total length; hence, a multiband antenna is achievable. At the same time, the same design has been applied on silicon substrate, and the measurement of radiation pattern is underway.

A method to effectively suppress the reflected wave of the short leaky-wave antenna and to perform two-directional scanning patterns on two different planes was presented. This proposed structure is made up of two types of antennas feeding in series. One of them is a microstrip short LWA, whose scanning beams are radiated above the ground plane. The other beam-scanning antenna is a linear array of phase-controlled aperture-coupled patch antennas that radiate below the ground plane. This designed array scanning capability is suitable for military application, air traffic control, collision avoidance system, or radiolocation, etc. Thus, there is great potential for application in the future.

6-2. Future Study

The results presented in this dissertation are works in progress, and hence there are still other efforts being underway. Therefore, in this section, future works of these applications or technology are described.

6-2.1 Design of the novel RF MEMS switch and phase shifter

Switches are fundamental enablers of many RF and microwave circuits and system functions; for instance, tunable matching networks, T/R switches, switching matrices, and phased array antennas [1]~[2]. As a result, RF switches play the key roles in the front-end subsystems in the whole wireless communication system. Nowadays, there are three popular solutions for the drawbacks of the traditional switches; the Pin diodes, GaAs FETs and MEMS switches. The switches of the phase shifter we use in Chapter 5 just belong to first kind. Conventional microwave switches show the disadvantages of large volume and unbearable weight and the semiconductor switches execute worse performance in the high frequency domain. In this study, we exploit the MEMS technology to implement this novel seesaw-like RF switches to broaden its application and use the MEMS switches to accomplish a phase shifter by combining the MEMS switches and nonlinear delay line. We plan to use this MEMS phase shifter to replace the Pin diodes in Chapter 5

A two bits MEMS true-time delay network by composing MEMS switch was designed. There are two CPW transmission lines with different lengths located in two sides of switch and the whole network is constructed on the Si substrate. In Fig. 6-1 and Fig. 6-2, the layout and schematic of our proposed MEMS switch and CPW phase shifter circuit are shown. It is a two bits MEMS true-time delay network composing of novel designed seesaw-like MEMS RF switch. There are two CPW transmission lines with different lengths located on two sides of switch and the whole network is constructed on the Si substrate. The purpose of the contact is to conduct the signal lines; the torsion bars act like the spring. And the two lines are designed to be normally open and can be selected by controlling the switch contact. Only after the conduction is enabled, only one transmission line can deliver the RF signal. Since the two transmission lines are of different lengths, which presents two different phases. In the future, this MEMS phase shifter can then replace the Pin diodes used in Chapter 5.

6-2.2 Fabrication of Lateral Micro Switch/Relay

The potential of RF-MEMS is its possibility to integrate RF-MEMS components with mainstream IC technology to yield integrated RF-MEMS systems. By using materials such as silicon and fabrication techniques compatible with IC technology, MEMS mechanical components can be made monolithically integrated with electronics, producing a complete and smart system-on-a-chip that interacts with the physical world, performs electronic computations, and communicates with other systems.

In addition, it is valued to integrate RF-MEMS components, which often require thick conduction metal layer with low-loss from substrate, with system IC either in a monolithic way (SoC) or hybrid fashion (SiP) [3]~[6]. Here, we presented a novel platform technology, EPIES (Electroplating and Isotropic Etching Silicon), for integrated RF-MEMS system-on-chip. The reported EPIES technology uses thick high conductivity plated Cu and released the component structure by XeF_2 isotropic Si etching to reduce the RF loss from the conducting substrate. The process is low temperature and CMOS IC process compatible. In the near future, the high-Q RF components can be integrated to form RF system-on-chip (SOC) by introducing this platform technology.

The process flow of EPIES is shown in Fig. 6-3 [7]. And Fig. 6-4 shows the cross-section SEM photography of Cu structure after the XeF_2 isotropic Si etching. The Si substrate was isotropic etched by XeF_2 to release the plated Cu structures. Figure 6-5 (a) and (b) show the SEM photography of Cu micro relay/switch and tunable capacitor after the XeF_2 isotropic Si etching. The Cu structure is successfully released as figure shown. To increase the electrostatic force between the fingers, the space between should be as small as possible. In this work, the smallest space of the fingers is about ~ 2 μm. There are many other issues may influence the driving mechanism of the relay/switch. The structure design, the cantilever width, the finger number, the space between the fingers, the metal thin film stress, and etc, are all possible to change the driving mechanism of the relay/switch. These issues will be significant for the further investigations.

The driving characterization of these lateral contact type relay/switch fabricated by EPIES process was measured in this work. As discussed above, the EPIES platform is much suitable to fabricate the low driving voltage RF-MEMS components, such as MEMS inductors, tunable capacitors and resonators. During the operation of these components, the structure will not need to contact each others. Therefore, the contact factor can be eliminated. The high Q structure (the released Cu metal) and the low loss (isotropic etched) substrate can be fabricated after the conventional CMOS IC process. The RF-MEMS SoC can be achieved. In conclusions, we present a novel platform technology, EPIES (Electroplating and Isotropic Etching Silicon), for integrated RF-MEMS system-on-chip. This platform technology is simple and easy to use, IC process compatible, and suitable for the integrated RF-MEMS-SoC.

6-3. References

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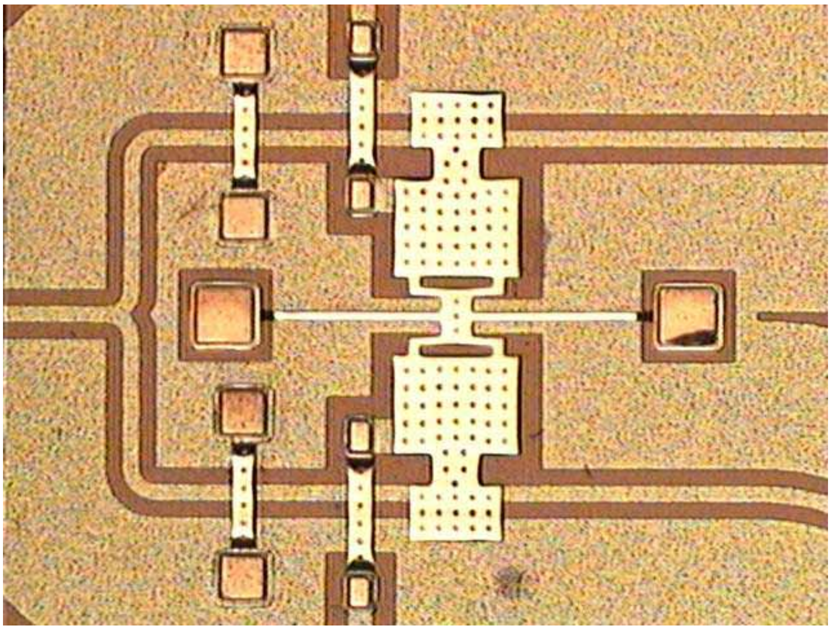


Figure 6-1: Layout of torsion RF MEMS switch and CPW circuit.

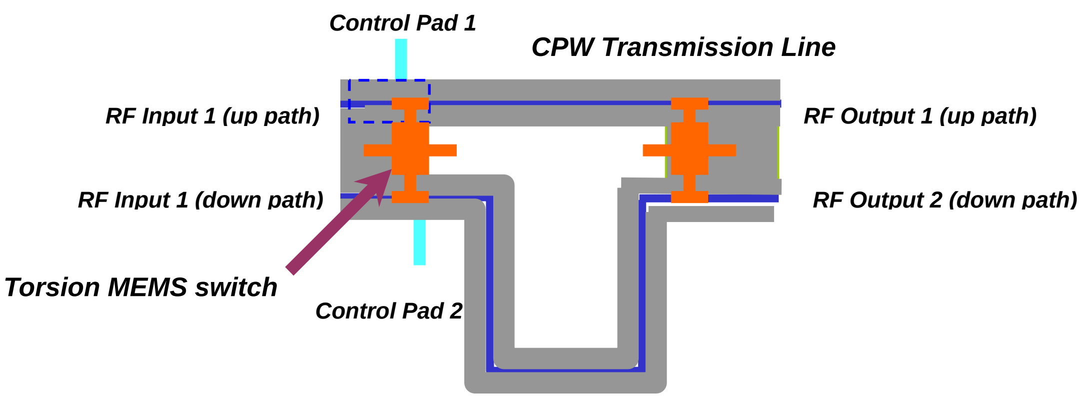


Figure 6-2: The schematic of CPW nonlinear delay line.

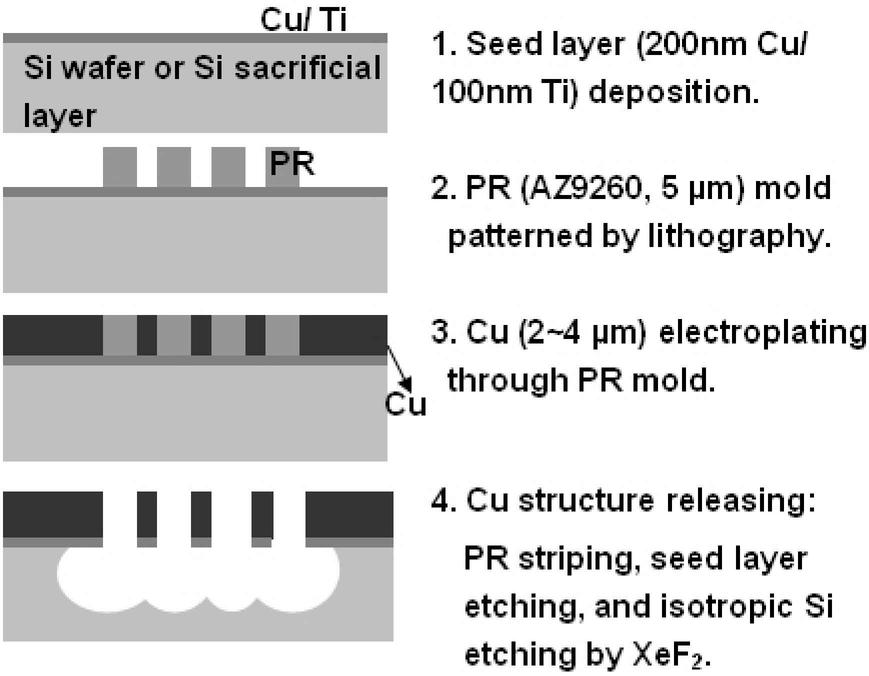


Figure 6-3: Brief describe of EPIES process. (6-3. [7])

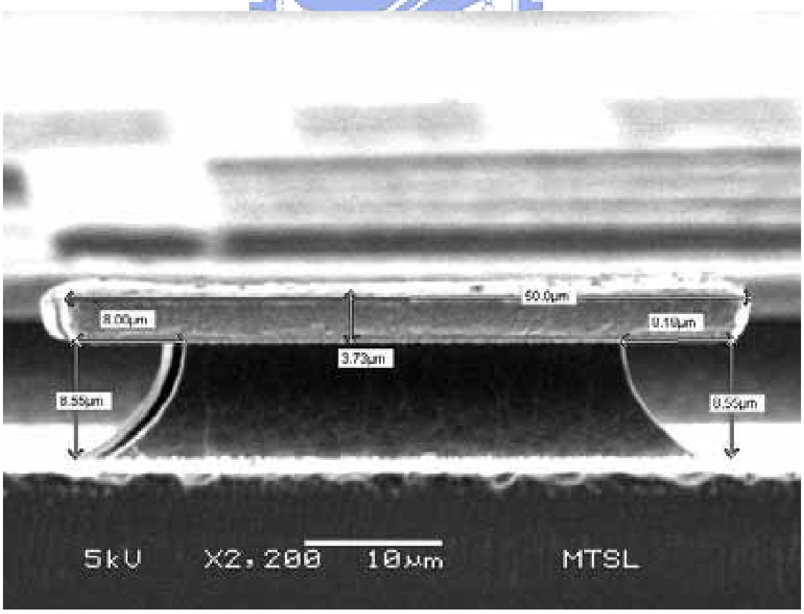
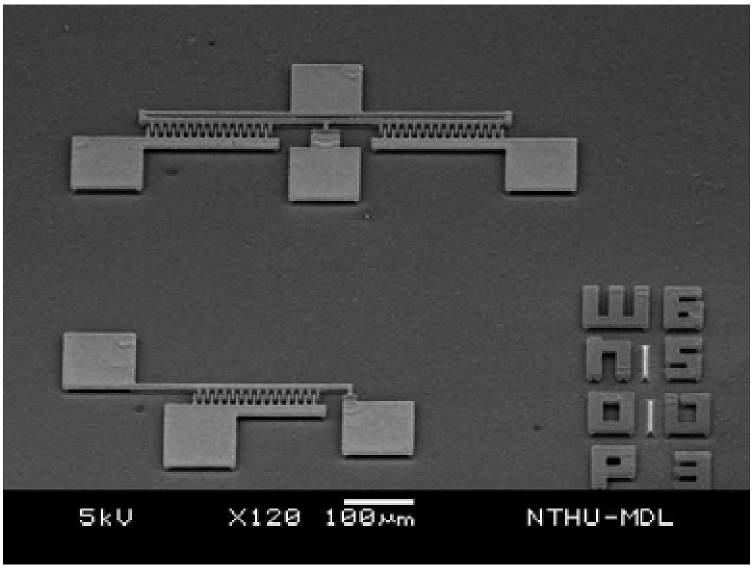
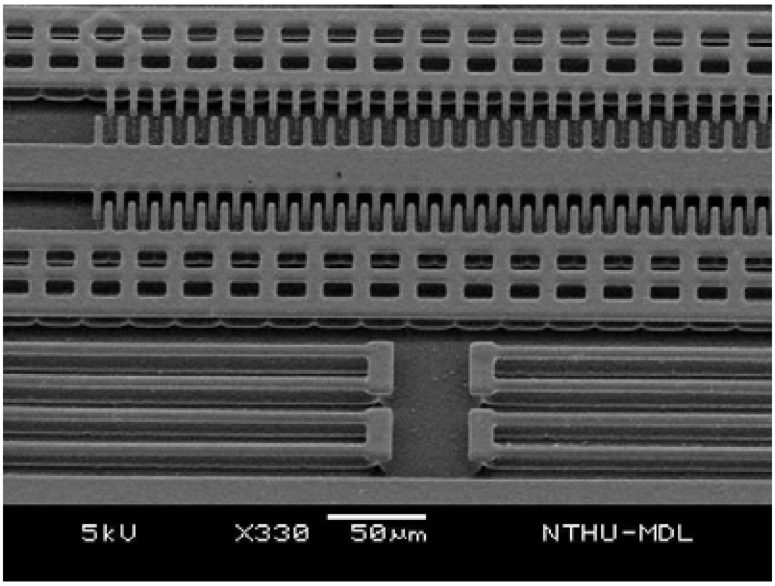


Figure 6-4: The cross-section SEM photography of Cu structure after the XeF_2 isotropic Si etching. (6-3. [7])



(a)



(b)

Figure 6-5: The SEM photography of Cu (a) relay/switch and (b) tunable capacitor after the XeF_2 isotropic Si etching.