Strain-Sensitive and -Insensitive Stretchable RF Patch Antennas

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Abstract

As the critical component in the wireless communication systems, RF patch antennas fabricated on elastomer materials have attracted widespread attention and have been developing rapidly [1,2]. In general, stretchable RF antennas could be used in two primary cases : 1. In the first case, the electrical characteristics of a stretchable antenna are sensitive to the stretching of the soft substrate, so that a characteristic signal is generated in real-time for the monitoring of soft substrates morphological changes; 2. In the second case, the electrical performance of a stretchable antenna is insensitive to the deformation of the carrier, so that the performance of the wireless communication system is not significantly impacted under mechanical strain. Therefore, according to the different requirements of the above application scenarios, it is important to select the appropriate antenna type, and to alter the fabrication processes for the antenna in order to fit the elastic substrate and conductive material properties accordingly. The performance of the antenna will then become related not only to the frequency domain, but also to the strain of the substrate [3]. A general, simple method for the design, fabrication and application of stretchable RF patch antennas is highly desired.

We proposed a practical and simple processing flow as shown through Figures 1(a) to 1(i). During the metal thermal evaporation, the PDMS substrate is intentionally pre-strained (1%~10%) as shown in Figure 1(f) in order to form metal wrinkles on the surface when relaxed. Figure 1(j) and 1(k) compare the surface morphology of the Au/Ni metal layers under different post-strain conditions, which shows “fishing net” contains smaller crack domains under 130% strain. The gaps between domains changes minimally and are negligibly small compared to the operating wavelength of the antenna in the GHz range. RF signals are able to pass across the gaps between metal domains easily by large electrical field coupling. As a result, the conductivity of the Au/Ni metal bilayer fabricated in the proposed way is affected little by stretching the substrate up to 140% at RF frequencies. Within a reasonable range of strain variation from 110% to 140%, the measured PDMS thickness and resulting relative dielectric constant as a function of strain is shown in Figure 1(l), and the expected trend of dropping characteristic impedance of microstrip transmission line when the PDMS substrate is stretched along the transverse direction is shown in Figure 1(m). Compared to traditional antenna design principle represented by equation (1) and based on FEM modeling and an artificial neural network (ANN) optimization algorithm, equation (2) summarizes the condition for an acceptable design of a stretchable antenna. Based on the above design route, a transmit-receive system using the two stretchable antennas attached conformally to a human wrist is setup as shown in Figure 2(a). It can be found from the amplitude of the received signal *v.s.* frequency plot (Figure 2(b) and 2(c)) that, for the stretchable monopole antenna, the received signal is relatively stable no matter how the wrist moves, and for the stretchable microstrip patch antenna, the frequency for which reception changes from 6 GHz to 5.6 GHz when the wrist moves. The two examples reported here suggest that the proposed design

and fabrication methods for stretchable antennas provide remarkable levels of conformability to deformable substrates.

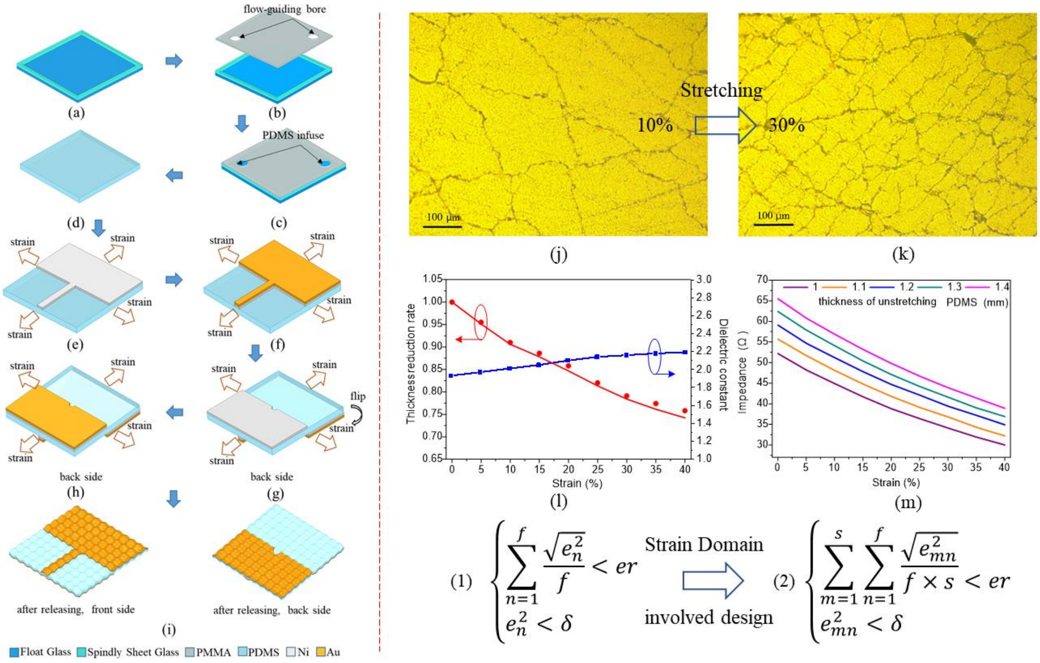

Figure.1 Fabrication and design route for stretchable RF patch antennas. (a)~(i) fabrication processing flow with pre-strain strategy for improved stretchability of conductive layer at high frequency. (j) ~ (k) surface morphology of conductive layer under different applied strain. (l) ~ (m) Measured and calculated PDMS substrate thickness, dielectric constant and impedance of microstrip line on top of it in terms of applied strain up to 40%. Equation (1) and (2) represent the design principle of antenna with/without considering strain domain *s* (*f*: frequency, e_r: overall acceptable error, δ: frequency point error).

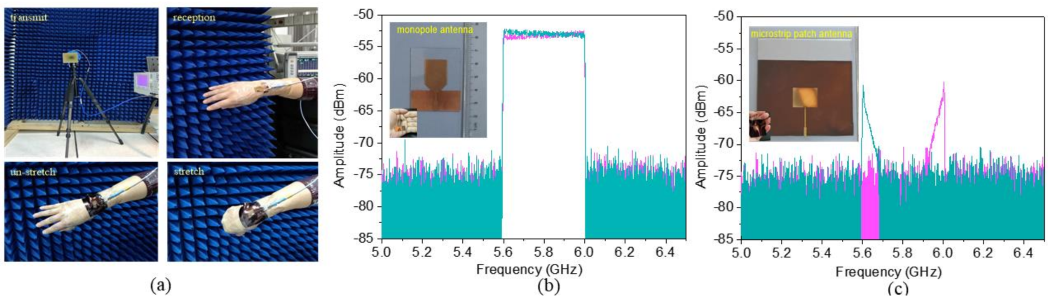

Figure.2 The demonstration of the two stretchable antennas. (a) The simple transmit-receive system. (b) The comparisons between the relaxed status and stretched status of the monopole antenna. (c) The comparisons between the relaxed status and stretched status of the microstrip patch antenna.

References

[1] Sallam, M.; Kandil, S.M.; Volski, V.; Vandenbosch, G. E. A.; Soliman, E. A.: Wideband CPW-Fed Flexible Bow-Tie Slot Antenna forWLAN/WiMax Systems. IEEE Transactions on Antennas and Propagation, Vol. 65, No. 8, pp. 4274-4277, 2017.

[2] Yan, S.; Soh, P. J.; Vandenbosch, G. A. E.: Wearable Dual-Band Magneto-Electric Dipole Antenna for WBAN/WLAN Applications. IEEE Transactions on Antennas and Propagation, Vol. 63, No. 9, pp. 4165-4169, 2015.

[3] Lacour, S. P.; Jones, J.; Wagner, S., Li, T., Suo, Z.: Stretchable Interconnects for Elastic Electronic Surfaces. Proceeding of the IEEE, Vol. 93, No. 8, pp. 1459-1467, 2005.