50 Years Ago

Much excellent archaeological work has been done on Stonehenge … It has been established that there was building activity from approximately 2,000 B.C. until 1,500 B.C. At the beginning of this period the 56 Aubrey holes were dug at equal spacings around a circle with errors of less than 0.5°. At the final phase the giant trilithon archways were in position, surrounded by the sarsen circle … Positions of all stones, holes and midpoints were measured … The machine programme called for the positions of stones, stone holes etc., in selected pairs, and the azimuths and horizontal declinations were computed. These alignments were then compared with the positions of the celestial bodies, and the errors of alignment computed. Stars and planets yielded no detectable correlation … The Sun yielded 10 correlations; to a mean accuracy of 1.5° the Moon gave 14.
From *Nature* 26 October 1963

100 Years Ago

The Gypsy Lore Journal is largely devoted to an account by Mr. E. O. Windstedt of "The Gypsy Coppersmiths' Invasion of 1911–1913." Owing to the reticence displayed by these people, the origin of the party which visited England is uncertain. … They appear to be genuine Gypsies, their skin colour being practically identical with that of the Russian peasantry. In their metal work there are remarkable coincidences with Indian art products. This monograph contains a very complete account of their religious beliefs, organisation, dress, manners, and customs. The excellent work being carried out, with very limited resources, by the Gypsy Lore Society … should invite support from all who are interested in this remarkable race and from students of anthropology.
From *Nature* 23 October 1913

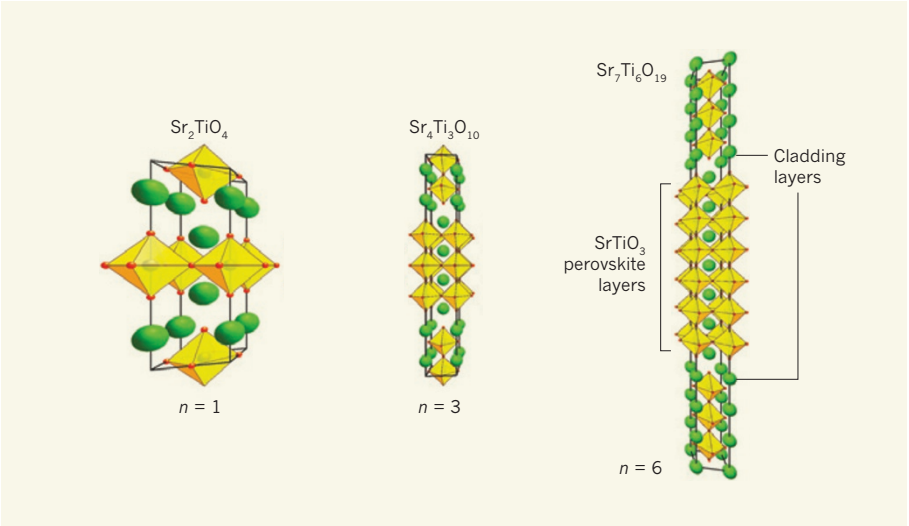

Figure 1 | The Ruddlesden–Popper series of structures. The $Sr_{n+1}Ti_nO_{3n+1}$ crystal structures studied by Lee *et al.*[3] consist of perovskite $SrTiO_3$ layers sandwiched between SrO cladding layers. Structures with $n = 1$, 3 and 6 are displayed. Strontium atoms are represented as green spheres; titanium atoms are in the centre of the octahedra (yellow), with oxygen atoms (red spheres) at each apex.

the ultimate material for tunable microwave devices.

The authors' approach was to begin with an inherently low-loss dielectric (insulator) material system that is related to BST, namely, the Ruddlesden–Popper series of structures, $Sr_{n+1}Ti_nO_{3n+1}$, and to engineer it to improve its tunability. To appreciate the engineered design that the authors have achieved at the atomic level, one needs first to visualize the structure of these materials. They are composed of perovskite $SrTiO_3$ layers situated between terminal SrO cladding layers (Fig. 1). These structures have been known for more than 50 years, but they are essentially dead when it comes to electronic tunability. Two years ago, theorists predicted[4] that, under biaxial tensile strain, a ferroelectric structural instability — which consists of the cooperative motion of each positively charged titanium cation moving against the surrounding negatively charged octahedron of oxygen anions — emerges in the Ruddlesden–Popper phases. Such ferroelectric instability is exactly what is responsible for the electronic tunability in BST.

The unusual prediction[4] about these Ruddlesden–Popper phases, however, is that this ferroelectric instability is local to each $SrTiO_3$ layer and occurs only if the spacing or distance between the terminal SrO cladding layers is large enough. In other words, the insertion of a specified number, n, of $SrTiO_3$ layers will increase the distance between the two terminal cladding SrO layers; and at some critical value of n, a ferroelectric instability will occur and with it electronically tunable behaviour attained through the application of an electric field.

Lee and colleagues' theoretical calculations show that for n greater than 3 (that is, for three or more perovskite $SrTiO_3$ layers inserted in between the two SrO layers), a local ferroelectric instability occurs for these Ruddlesden–Popper films in which the crystal lattice is strained to match that of the underlying dysprosium scandate ($DyScO_3$) substrate. This innovation is particularly exciting to the materials-science community because there is now, for the first time, a control parameter, n, that can be used to manipulate the properties of a tunable dielectric to satisfy the low-loss and high-tunability demands required for electronically tunable microwave devices such as filters, delay lines and phase shifters. What's more, the approach does not involve adding undesirable atomic disorder to the system, which would increase its dielectric loss.

Armed with this theory, Lee *et al.* set out to test it experimentally. They not only validated the theory but also demonstrated that the temperature (T_c) at which the material undergoes a structural phase change, from the 'paraelectric' state above T_c to one with local ferroelectric order below T_c, could be manipulated by changing n, and that the SrO cladding layers serve to accommodate film non-stoichiometry. The latter discovery is particularly important because non-stoichiometric behaviour is usually accommodated by undesirable structural point defects that unfavourably enhance the material's dielectric loss. This alternative accommodation of film non-stoichiometry preserves the films' low-loss attribute. Detailed experiments revealed that $Sr_{n+1}Ti_nO_{3n+1}$ with $n = 6$ exhibited low loss and good tunability that was stable over a broad operational frequency range (1 kilohertz to 125 gigahertz). This behaviour is of paramount importance, because it shows that tunable devices composed of these films are frequency agile — that is, they can be used over a wide spectrum of frequencies with stable, predictable and enhanced performance.

As with all discoveries, there will always be naysayers who will not recognize new findings