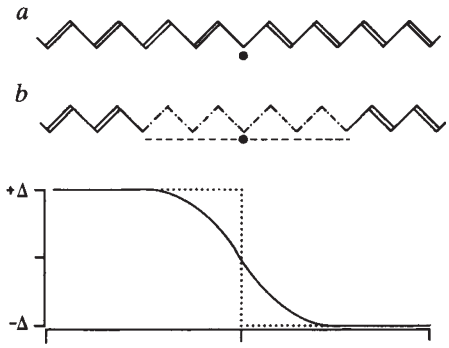

Fig. 2 *Trans* polyacetylene chain with a localized (Pople–Walmsley[2]) bond-alternation defect (*a*) and a delocalized (Su, Shrieffer and Heeger[3]) soliton (*b*). The change in phase (Δ) of the bond alternation for the two species is shown at the bottom of the figure.

Despite the apparent analogy with inorganic semiconductors such as silicon and germanium — indeed, the oxidation and reduction of polyacetylene is termed 'doping' — there are fundamental differences. The atoms in inorganic semiconductors are fixed in a three-dimensional lattice of strong chemical bonds. Thus the deformation produced by an injected electron or near an electron and hole (empty electron state in the valence band), produced by photo-excitation, is very small. In consequence the band structure calculated in the absence of excitation can be used to describe the excited states — the rigid-band model. In an ideal polyacetylene chain the chemical bonds are weaker and lie along a single direction. Thus the deformation caused by added and excited charge is much larger and gives rise to new states of the system.

In the case of an ideal polyacetylene chain, the alternation of double and single bonds can be reversed without changing the total energy. But the π-electron at a sharp boundary where the bond alternation is reversed, would produce a paramagnetic defect (Fig. 2). This was recognized theoretically long before its practical significance was realized[2]. Su, Schrieffer and Heeger[3] developed the theory and showed that the change in phase of the bond alternation need not be sharp. This extended spin defect can move along the ideal chain with a very small activation energy. It also adds an energy level between the valence and conduction bands of the polymer, which produces sub-band-gap optical absorption and has unusual spin–charge relationships. The electrically neutral defect has an unpaired electron with spin 1/2, but charged states with zero spin that can conduct are produced by either removing or adding an electron (Fig. 3). Because the hamiltonian equation introduced by Su, Schrieffer and Heeger to describe the defect is analogous to other nonlinear wave equations, the defect is termed a soliton.

A lively debate has evolved concerning the existence of solitons[4,5]. Experiments provide evidence both in favour of and against the model. It is clear that the defects associated with charge carriers in real materials, where the polymer chains are neither isolated nor defect-free, must differ from the original model of Su, Schrieffer and Heeger. For example, the paramagnetic defects will be localized by structural defects[6]. But there are signatures, particularly in photo-induced infrared spectra[7], that indicate that the structural relaxation associated with charge excitations in polyacetylene is similar to that in the ideal soliton.

The presence of soliton mid-gap states should influence the behaviour of semiconductor devices constructed with polyacetylene. The device performance realized with polymer prepared directly by catalysed polymerization of acetylene has been too poor for this to be demonstrated[8]. Control over purity and morphology is provided by the 'Durham' precursor route[9,10] (Figs 1 and 4). The soluble precursor polymer is purified by repeated precipitation and deposited by spin coating to give large-area films of uniform thickness. Burroughes *et al.*[1] use this approach to produce polyacetylene devices — diodes and transistors — with performances several orders of magnitude better than those reported by previous workers.

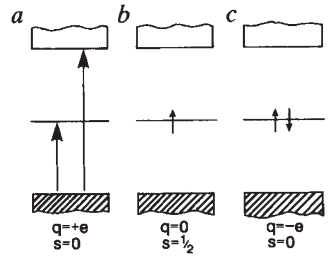

Fig. 3 Charge–spin relationships for different occupancy of the mid-gap energy level of a solitonic defect on a polyacetylene chain. Transitions to and from the mid-gap state give rise to sub-band-gap absorption, illustrated for the positively charged soliton at left.

They demonstrate that charge depletion and accumulation occurs at polymer–metal and polymer–insulator interfaces under the influence of an applied voltage in a way analogous with conventional silicon semiconductor–metal and –insulator interfaces. Thus in the metal–insulator–semiconductor field-effect transistor (MISFET; see Fig. 1 of Burroughes *et al.* on page 138), a voltage applied across the insulator layer causes charge to accumulate at or to be removed from the polymer–insulator interface. This changes the occupancy of the mid-gap levels, rendering the polymer conducting (Fig. 3), so that a current can pass between the source and drain electrodes attached to it. The change in occupancy of the mid-gap states can be monitored by the changing infrared absorption spectrum of the device as the fields are altered.

Thus the way of introducing charge

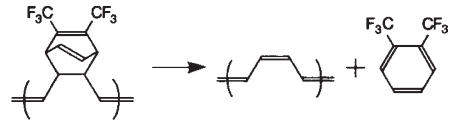

Fig. 4 Durham precursor route to polyacetylene, conversion is effected thermally and also results in the transformation of the initial *cis* polymer into the *trans* form (see Fig. 1).

Reference reagents for antinuclear antibodies

Reference antinuclear antibodies

Reagent	Immunological features
AF/CDC1	Homogeneous pattern ANA. Doubles as anti-native DNA
AF/CDC2	Anti-SS-B/La
AF/CDC3	Speckled pattern ANA
AF/CDC4	Anti-U1 RNP (U1 small nuclear ribonucleoprotein)
AF/CDC5	Anti-Sm (U1, U2, U5, U4/6 small nuclear ribonucleoproteins)
AF/CDC6	Nucleolar pattern ANA
AF/CDC7	Anti-SS-A/Ro
AF/CDC8	Centromere pattern ANA
AF/CDC9	Anti-Scl-70 (DNA topoisomerase I)
AF/CDC10	Anti-Jo-1 (histidyl-tRNA synthetase)

AUTOANTIBODIES to nuclear and other intracellular antigens, often called antinuclear antibodies (ANAs), are useful as diagnostic aids in clinical medicine and as immunological probes in molecular and cell biology. Two international organizations, the International League Against Rheumatism (ILAR) and the International Union of Immunological Societies (IUIS), have now set up an International Committee on Antinuclear Antibodies at a meeting at the World Health Organization in Geneva. The committee will standardize reference sera containing ANAs of different immunological specificities and, in collaboration with the Arthritis Foundation (AF) and the Centers for Disease Control (CDC), will make these reference reagents available to clinical laboratories and research investigators. The table shows the reference ANAs now available. They can be obtained from the AF/CDC ANA Reference Laboratory, Immunology Branch, 1-1202 A25, Centers for Disease Control, Atlanta, Georgia 30333, USA. □

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