

Relative yields of the Pokhran and Chaghai nuclear explosions

Recently there has been renewed interest in the yields of the Indian and Pakistani nuclear devices that were exploded in Pokhran, Rajasthan on 11 May 1998 and Chaghai, Pakistan on 28 May 1998, respectively. Furthermore, there has been some debate that the Pakistani explosions were 'duds' and the contrary viewpoint has also been expressed, that the Pakistani devices indeed were better than the Indian devices. The purpose of my note is to draw attention to the fact that the outcome of this debate is already settled in data published in the article by Harsh Gupta *et al.* (*Curr. Sci.*, 1999, **76**, 1117–1121).

I wish to draw your attention to Figure 6 in the aforementioned article. The authors have plotted on the same diagram the spectral characteristics of the explosions as registered at monitoring stations in India and equidistant from the sites of the explosions at Pokhran and Chaghai. In particular, the authors have plotted frequency along the x -axis and normalized or some re-scaled energy along the y -axis. It is clear from this figure that one cannot compute the individual yields of the devices, but the relative yields of the devices can easily be obtained by a routine computation as explained here.

Firstly, extend (extrapolate) the right most arms of the graph, of say the graph for the Indian explosion as detected at Bilaspur, linearly until it cuts the x -axis. Then perform a similar operation for the graph for the Pakistani explosion as detected at Bhuj. The errors that will arise by such extrapolations are miniscule since the energy content in higher modes as clearly seen from the figure is diminishing rapidly. One could also, in principle, have chosen not to extrapolate. Next, elementary Fourier analysis and Plancherel's theorem in particular tells us that the area under the graph is a measure of the size of the explosion. To calculate the area under the graphs, simply use graph paper of reasonable size, paste it under the graphs and count the squares. Alternatively, one can use numerical algorithms like the Simpson method as taught in elementary calculus courses to compute the area under the curve. The returns from such a refined method are actually little and the graph

paper method is a quick and simple reckoner. Going back to our problem, one finds that the area under the graphs for Pokhran = 170 and Chaghai = 84.

The individual numbers are unimportant since the authors are using a scaled energy along the y -axis. But clearly the ratio is important and easily is seen to be about two. Thus we see the seismic data presented in Figure 6 easily give the relative yields. One can make the following conclusions:

- (1) Since the Indian devices were reported to have a total yield of approximately 60 kt and this was further corroborated in particular by the article by S. K. Sikka *et al.* (*Curr. Sci.*, 1999, **77**, 1669–1673), the conclusion one arrives at based on Fourier analysis is that the Pakistani devices had a combined yield in the vicinity of 30 kt.
- (2) I also suggest that Gupta *et al.* subject their seismograms to a wavelet analysis, rather than a Fourier analysis, as they have done. It will reveal a far finer structure than Fourier analysis will. In particular, it may not be overly ambitious to suggest that wavelet analysis may even reveal how many explosions were set off at the various test sites.

Lastly, I wish to thank D. Ramana and V. Natarajan who drew my attention to the article by Gupta *et al.* in *Current Science*. I also thank S. Badri-Maharaj and Diptiman Sen (IISc) for making helpful comments that clarified the situation.

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Reply

In our article (*Curr. Sci.*, 1999, **76**, 1117–1121), we had investigated the spectral characteristics of the 11 May 1998 Pokhran, India and 28 May 1998

Chaghai, Pakistan nuclear explosions. The purpose of our analysis was to demonstrate that the broadband seismic data permits convenient spectral analysis to comment on the characteristics of seismic sources. We had used the broadband data of a number of seismic stations and demonstrated that the energy from the Pokhran explosion peaked in the frequency range of 3.5 to 6 Hz compared to a range of 1 to 3 Hz for the Chaghai explosion. We had made no attempts to estimate yield of the explosions or make a comparative study of them. We have not carried out Fourier analysis, but determined the energy contents in frequency bands in time domain by passing the seismograms through various narrow band-pass filters.

As suggested by Sagun Chanillo, one could subject the signals to wavelet analysis to find out the finer details of the explosions.

We are thankful to S. Chanillo for his positive comments on our paper.

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Editors' note: In view of the interest in yield estimates of the nuclear explosions from available data, we obtained comments on the letters from an independent reviewer, which are reproduced below:

In the comments on the article by H. K. Gupta *et al.* (*Curr. Sci.*, 1999, **76**, 1117–1121), Sagun Chanillo attempts to find relative yields of Pokhran and Chaghai tests based on the P wave spectra provided in the above paper using a simple assumption that the area under the spectrum will be proportional to the yield of the explosion. This assumption is valid only if the source parameters of the ex-

plosions and signal attenuation characteristics along these paths are identical, and the signals are observed at similar distances. However, the distance of Chagai to Bhuj is 7.7° and that of Pokhran to Bilaspur is 10.5° . Moreover, the

source parameters and signal attenuation along the propagation paths between the source and the receiver for these explosions, are not known. Further, it is well known that at regional distances of this order there is a large variation of signal

amplitudes for different propagation paths. Hence for getting a realistic estimate of yield ratio between Pokhran and Chagai explosions using only P waves, it is necessary to incorporate path and source corrections in the spectra.

NEWS

Conducting polymers: Nobel Prize in Chemistry, 2000

The Nobel Prize in Chemistry¹, 2000 has been awarded to Alan J. Heeger² (University of California at Santa Barbara, USA), Alan G. MacDiarmid³ (University of Pennsylvania, USA) and Hideki Shirakawa⁴ (University of Tsukuba, Japan). The citation for the reward – ‘for the discovery and development of electrically conductive polymers’. Moreover, The Royal Swedish Academy of Sciences¹ pointed out that the award is being motivated by the ‘important scientific position that the field has achieved and the consequences in terms of practical applications, and of interdisciplinary development between chemistry and physics’.

The conventional wisdom suggests that polymers (plastics, rubbers, etc. used in everyday life) offer substantial resistance to the flow of electricity; and being widely used for electrical insulation purposes. In usual carbon-based polymers, the sp^3 carbons form sigma-bonds, as a result the electrons are in bound state. Due to this, there hardly exist any free charge carriers to assist the flow of electric current in common polymers. Hence, the term ‘conducting polymer’ was considered as an oxymoron till late 1970s. Moreover, before the advent of organic conductors⁵ in early 1970s, the prevalent view was such that electrical conduction mainly occurs in inorganic systems like Cu, Si, etc. (with the exception of graphite) due to the presence of delocalized electron sea; whereas, in organic and biological systems the electrons are localized by covalent bonding, hence not really conducive for electrical transport due to the lack of free/delocalized charge carriers, low mobility of carriers, etc.

From the early works of Pople and Walmsley⁶, Salem⁷ and Little⁸, it is known that in a linear chain of sp^2 carbon atoms, consisting of alternating single and double bonds, the delocalized π -electron cloud can attribute special features to the electrical and optical properties in organic systems. For example, β -carotene, the orange pigment in carrots, consists of nine repeated alternating single-double bond units (conjugated bonds). The delocalized π -electrons in these single-double bond units induce a blue-shifted absorption, hence gives the orange colour to carrots. Since the π -electrons are less bound to the carbon nuclei, they require less energy to go to the excited states. This type of strong absorption of light in the visible region is one of the special features of molecules containing conjugated repeat units.

The simplest example of a polyconjugated system consisting of several repeat units of (CH_2) is polyacetylene $[CH_x]$, as shown in Figure 1. After the discovery of Ziegler–Natta catalysts,

Natta and coworkers⁹ attempted to synthesize CH_x by bubbling acetylene gas through a titanium/trialkyl catalyst solution, in the year 1958. The main product of the reaction was a black, semicrystalline powder; and it was completely insoluble, infusible, and unstable in presence of air and water. In 1971, Shirakawa and Ikeda¹⁰ found that $Ti(Obu)_4/AlEt_3$ yields CH_x exclusively, in the form of polycrystalline/flexible film. This work revolutionized the field of polyacetylene chemistry and physics, also this opened up the field of conducting polymers. Shirakawa and coworkers¹¹ further optimized the synthesis of CH_x by using higher concentration of catalyst to produce dense and tough free-standing films.

In a typical CH_x synthesis¹¹, $Ti(Obu)_4$ was added to a Schlenk flask with 20 ml of toluene followed by the addition of 4 equivalents of $AlEt_3$ in an inert atmosphere. The catalyst was aged for 30 min at room temperature. The catalyst solution was degassed at $-78^\circ C$ and then slowly rotated to coat the wall of the

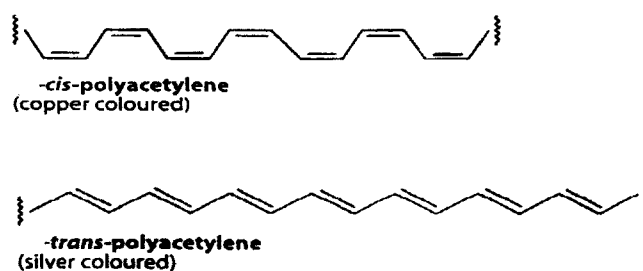


Figure 1. *Cis* and *trans* structure of polyacetylene.