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Quantized conductance in an atom-sized point-contact - Reply

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Olesen *et al.* Reply: In their Comment Krans *et al.* [1] raise two points. First, they argue that the theoretical treatment in our recent Letter [2] is too simple and does not *prove* the existence of quantized conductance jumps in a contact between an STM tip and a metal surface. Secondly, they question whether the experimental results we provide actually show a quantization of the conductance in units of $2e^2/h$ as we claim. Their point is that some of the conductance plateaus in our experiments are not exactly at integer values of this conductance unit and they also provide experimental results of their own (for a different experimental situation), showing that often there are no well-defined conductance steps at all or the steps are very far from the integer values.

Before entering into a discussion of the theoretical description of the conductance in these point contacts, let us discuss the question whether a quantization in units of $2e^2/h$ is observable at all. This must be the starting point for the discussion. In Fig. 1 we show a histogram of 59 conductance measurements over a Pt(100) surface. The histogram contains all the measurements in a series of STM indentations and extractions. Only those showing a stable tip before and after indentation and where there are no signs of impurities have been included. The results clearly show a grouping of the experimental observations around the integer values of the fundamental conductance unit. This strongly points towards conductance quantization. Further, we find the same picture for Cu and Ni. We therefore disagree with the second part of the Comment by Krans *et al.* Conductance steps can arise solely from mechanical instabilities, but we cannot see why this should lead to peaks at one, two, three, and four times $2e^2/h$ and why they should be independent of the metal.

Returning now to the theoretical discussion in our Letter, we are of course not claiming that we can prove (or disprove) conductance quantization in a particular set of experiments theoretically. Rather, we simply point out that the natural way to think about conductance in a point contact is in terms of the Landauer theory (see Refs. [3] and [4] of [2]) and quantization of the electron states perpendicular to the contact.

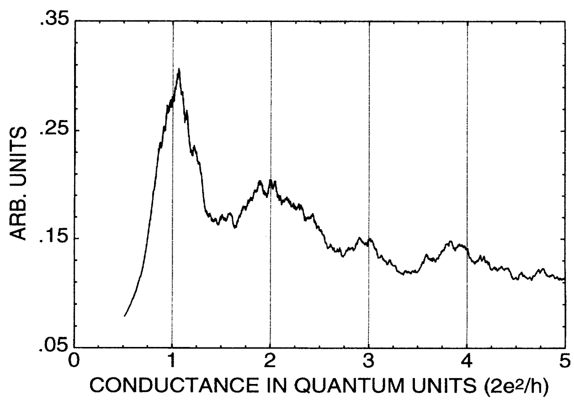

FIG. 1. A histogram of all measured conductances during the pulling of point contacts made by indenting a W STM tip into a Pt(100) surface.

In Ref. [1] Krans *et al.* argue that scattering due to the atomic structure and the irregularities of the contact could destroy the quantization and therefore destroy the quantized conductance. Without getting into a more detailed discussion of this point here, let us mention that there are striking analogies in other branches of physics. Small metal clusters are also imperfect, but still show the quantization and magic numbers that come out of a simple jellium model [3].

It is evident that the quantization levels in Fig. 1 are not sharp, and we suggest that the scattering mentioned by Krans *et al.* is responsible for this. The fact that there are well-defined peaks shows that the free-electron model is a good starting point for understanding these phenomena. In a forthcoming paper we will discuss this in greater detail. We mention finally that whether we average before or after quantization makes a very modest change to the results.

We therefore maintain that our measured conductances in STM point contacts show a clear tendency for values that are an integer times $2e^2/h$. We also maintain that this main feature of the experiments must be understood in terms of a quantization of the electron motion in the contact. The experiments also show signs of scattering. This is interesting and requires further theoretical study, but does not affect the main conclusion of our Letter [2].

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[1] J.M. Krans *et al.*, preceding Comment, Phys. Rev. Lett **74**, 2146 (1995).
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[3] T.P. Martin, U. Näher, and H. Schaber, in Proceeding of the International School of Physics "Enrico Fermi," Course CXXI (North-Holland, Amsterdam, 1994), p. 139.

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